BULLETIN

OF THE

SCIENTIFIC LABORATORIES

OF

DENISON UNIVERSITY,

EDITED BY
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VOL. I.

GRANVILLE, OHIO, DEC., 1885.

Downs & Kussmaul,
PRINTERS,
Granville Ohio.

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EDITORIAL STATEMENT.

Every well conducted institution of learning should form a recognized centre of scientific activity; and legitimately concerns itself, not only with the instruction of those who directly entrust themselves to its charge, but with the dissemination and conservation of information relating to the subjects taught. Moreover, in connection with the laboratory drill, it often happens that facts of general scientific interest are brought to light which the student may be ill prepared to appreciate in all their bearings. Such facts, if preserved, may, at another time, become very valuable, while, if not thus preserved, they would be lost. Still again, instructors will, as a rule, be unable to instill enthusiasm if they themselves do not come in contact with nature at first hands, while the fragments of time, which are often frittered away, can be made most useful to themselves and others by being applied to studies in advance of the work required by the curriculum.

The present publication, which we are able to present through the generous co-operation of numerous friends, is a step toward filling a need hinted at in the above paragraph. The bulletin is intended to represent the life of the college in its scientific departments and may incidentally serve to illustrate to distant friends the facilities for work afforded, as well as needs still unsupplied. To the scientific students of the country we confidently appeal for support and indulgence, since it is hoped to devote an increasingly large portion of space in each number to technical papers which have more interest to the student than to the general public. To the teacher, with still greater confidence, we look for encouragement, as it is entirely in the interest of better school work that this bulletin is prepared. While limited means has, in this first number, prevented the use of costly illustrations, it is hoped that the generous patronage of this volume will enable us to extend to the contributors to the following one more elegant, if not more perspicuous graphic aids.

A considerable number of papers prepared for this number have been necessarily delayed, on account of the limited space allotted, and yet our limits have been extended. The lithographs were executed by the editor and printed by a process making them cheaper than any other available, and any failure to realize the ideal of such work will, no doubt, be pardoned on this account.

For information relating to the departments here represented, the reader is referred to the advertisement appearing elsewhere. The fact that the chemical laboratory has afforded us no material for this number, may be attributed to the change in administration in that department, occasioned by the death of the lamented Prof. Osbun.

I.

THE EVENING GROSBEAK—*Hesperiphona vespertina, Bonap.*

[PLATE I AND FRONTISPIECE.]

Among the rarities in the cabinet of most ornithological collectors is the Evening Grosbeak, which excites interest as much by its comparative rarity and exceeding capriciousness in distribution as on account of its odd note and eccentric behavior. First found by Mr. Schoolcraft, in 1823, near Sault St. Marie, in Michigan, it was described by Cooper. The indefatigable naturalist, Sir John Richardson, encountered it upon the Saskatchewan, where seems to be its natural home, and from whence it issues forth, guided by any whim, and wanders far to the East and South, though seeming to avoid the coast. The genus is Asiatic and our two species are obviously derived from the Old World, via Alaska. In Europe there is a closely allied genus *Coccothraustes*, which differs in the shape of the secondary wing feathers. The genus is distinguished from all other finches of the United States by the very large beak and the following points:

"Feet short; tarsus less than the middle toe; lateral toes nearly equal, and reaching to the base of the middle claw. Claws much curved, stout, compressed. Wings very long and pointed, reaching beyond the middle of the tail. Primaries much longer than the nearly equal secondaries and tertials; outer two quills longest; the others rapidly graduated. Tail slightly forked; scarcely more than two thirds the length of the wings, its coverts covering nearly three-fourths of its extent."—*Baird.*

[In America we have the two species, *H. vespertina* (with its two varieties), and *H. abeillii*, Scl., which lives in the mountainous portions of Mexico, southward.]

In very few places in the United States does this bird appear with sufficient constancy to be set down as more than an accidental visitor. In this respect Minneapolis, Minn., is particularly favored for, during a number of years, these grosbeaks have rarely failed to make a longer or shorter winter visit, sometimes coming early in the Autumn and remaining until the trees are in full leaf, when, in a few cases, their much

mooted song has been heard. The most eastern point yet reached by these birds seems to be Cleveland, Ohio, and isolated cases of their occurrence in Wisconsin and Illinois are also known. The species is highly gregarious and individuals are rarely or never met with singly. Even the destructive inroads of the collector, before whom they are absolutely defenseless, do not scatter or break up the flock. Unsuspecting and without fear, they continue to feed until the last individual falls a victim. The migrating colony seems well satisfied with itself and its temporary home and, while feeding, a constant chorus of answering cries is kept up. The note is not loud but is remarkably piercing, and yet not unmelodious. The early belief that these birds are silent except at evening is entirely erroneous. In spring, upon the approach of the breeding season, the males cultivate the muses in an odd but not displeasing little song. This song consists of several successive repetitions of a short warble, followed by a similar strain closing with a shrill cry, like the finale of a black-bird's song. The phrase which makes up the body of the song is musical, but is so abruptly terminated (as though from lack of breath or of ability,) that it is annoying when heard singly, for one is subjected to much the same nervous expectancy felt in listening to a hen's cackle when quite leisurely "working up the agony" sufficiently to sound the final note. A flock of a dozen or more singing together produce a very musical effect. The food almost entirely consists of the seeds of various trees, among which the box elder, the maple, poplar, and pine are pre-eminent. Buds of cherry and other trees are also eaten, and this regime is varied by occasional insect larvae, etc.

O. B. Johnson, who mentions this grosbeak from the Williamette valley, speaks of it as plentiful during migrations, and states that "the only note heard was a loud '*yeeip*,' strikingly like the call of a lost chicken." Of the nest and eggs we as yet know nothing, and so of the many interesting traits which make up the sum of its true home-life we must be content to remain ignorant. From its inaccessable summer home it continues to descend during the severe winter weather and, almost under the very roofs of the factories of a busy city, contentedly passes the short days, heedless of the noise and regardful only of the oily kernels of the keys of the box elder, which it displays a very awkward skill in plucking as it swings (head downwards or otherwise) from the pendulous branches.

These brief remarks are designed simply as introductory to the

notes on the osteology appended. Before preceding to these the following description will suffice to make the bird recognizable.

Sp. char. Bill, yellowish green, dusky at base; anterior half of body dusky yellowish olive, shading into yellow to the rump above, and the under tail coverts below. Outer scapulars, a broad frontal band continued on each side over the eye, axillaries, and middle of under wing coverts, yellow. Feathers along the extreme base of bill, the crown, tibiae, wings, upper tail coverts, and tail, black; inner greater wing-coverts and tertiaries, white. Length, 7.30, wing 4.30, tail, 2.75. In the female the head and back is dull olivaceous brown. Below, the body is pale yellowish ash. There is an obscure black line on either side the chin. There is more white upon the wings and tail. (See plate, which is intended to give simply the *tout ensemble* without strict accuracy as to color.)

Osteology of Hesperiphona vespertina.

The anatomy of the Evening Grosbeak is of more than usual interest, not only on account of the rarity of the bird and the air of mystery which has associated itself with it, but because it stands at the head of American *Fringillidae*, by virtue of possessing the extreme development of the finch type of structure. Our observations are based on the study of three more or less perfect skeleta, which, so far as we know, are the first which have been studied.

The skull. The most striking peculiarities of the skull are those which are corelated with the extraordinary development of the beak. The angle, for instance, formed by the quadratojugal-jugal bony pillar with the lower margin of the maxilla is greater than usual, chiefly on account of the great size of the quadrate bone. In this way a firm support is afforded to the upper jaw. But we pass to a detailed description. As seen *from above*, the skull is, in outline, a perfect triangle, with a narrow rounded base. The apex of the triangle is formed by the remarkably large and strong (though correspondingly very light) beak. The bones entering the beak are cancellated within, forming a firm but light organ. These bones are, first, the *premaxilla*, which makes up the bulk of the bony frame-work of the beak and is early anchylosed with the maxillaries in the family under consideration. Although we can not separate the parts, we may distinguish in the *maxillary* bone a superior or nasal process which separates the opening of the nares and unites with the nasal bones, two lateral or maxillary processes, and two palatine processes which are within the mouth-opening. The distance from the apex of the beak to the subcircular nares is .6 inches, the distance between them, .10. The *nasals* are inseparably

united and form a quadrate bone making an angle of 25° with the culmen or upper line of the beak, their combined width is .45, and they form the posterior borders of the nares, being united laterally with the maxillaries, anteriorally with the intermaxillary, below with the lachrymals, and posteriorly with the frontals. The distance from the angle of the mandible to the top of the nasals is .40. Occupying the top of the skull, and apparently restricted to the space between the orbits, are the concave *frontals*. The distance between the orbits is about .35. The remainder of the roof of the skull is formed by the confluent *parietals* which occupy a larger area than usual on the top and back of the skull. From above can be seen a small prominence behind, which covers the cerebellum, and hence is called the *cerebellar prominence*. The sides of the triangle are continued backward from the ends of the maxillaries by a slender rod consisting of the *quadratojugal* and the *jugal* which can be studied to advantage when the skull is viewed *from the side*. In this position the skull is seen to present the outline of two triangles, the smaller of which, forming the beak, is set at an angle of 45° with the other. The cutting edges of the jaw (*tomia*), supported chiefly by the *maxillary* bones, are slightly curved. The tomia are .80 long. The slender rod passing backward and downward and forming the lower outline of the second triangle is, in the young, composed of two bones, the jugal and quadratojugal. Their combined length is .54, the posterior articulation being upon the outermost process of the peculiar *quadrate* bone. This bone is considered the homologue of the little ear bone of mammals, known as the malleus, but in birds has a very important function—that of giving the necessary movability and yet stability to the beak. It is the point of attachment of the two important supports of the facial part of the skull. The form of the quadrate is very irregular, consisting of a body and six processes. The styloid process is the largest and is that which connects the bone with the base of the skull; it is a flattened vertical pillar with a large articular surface; jutting out anteriorly is the orbital process, about .30 long, which extends into the orbit. Just below the orbital is the pterygoid process of rather small size. The mandiblar end bears two curved processes so situated that the glenoid surfaces oppose the rami from within and behind, while the jaw is completely locked by the large articular process of the mandible. A more complete articulation could scarcely be conceived. The malar process extends out horizontally and offers an oblique surface to the head

of the quadrato-jugal. The *lachrymal* bone is very large and hoe-shaped, occupying the whole anterior aspect of the orbit. A very slender curved process extends backward from its lower angle. The lachrymo-nasal space between this and the maxillary permits the free movement of the beak on the skull. The lachrymo-nasal foramen is quadrate. The optic foramen occupies its usual position on the margin of the *ali-sphenoid*, which is inseparably united with the *septum intraorbitale* and this with the *ethmoid* still farther forward. There is a large irregular foramen above the optic. The greater part of the side of the skull behind the orbit is formed by the *squamosal*, which is strongly ridged and forms, first, a strong flange-like process behind the orbit and, second, a very long process projecting forward toward the corresponding process of the lachrymal. The *orbito-sphenoid* was not detected as a distinct bone, but irregular processes on the ali-sphenoid may represent it. The *sclerotals* are membranous bones, which unite to form a ring about the globe of the eye. As seen from below, several new bones appear. At the back of the skull is the large *foramen magnum*, subcordate and quadrate in form and about .20 in width. Above, it is bounded by the *supraoccipital*, laterally by the *exoccipitals*, and below by the *basioccipital*. These bones are intimately united and the sutures quite obliterated. There is an impressed line on either side the foramen. The single occipital condyle is a small knob-like process. The basioccipital is quadrate and near its lateral margins are the foramina of the carotid and the seventh, ninth, tenth and eleventh nerves. The *squamosal* expands into a large shield-like covering over the auditory meatus. Just inside of the quadrate bone can be seen a bony sheath which indicates the former point of union of the Meckel's cartilage. Within the meatus the minute auditory ossicles can be seen with a glass. The *sphenoid* is a pyramidal bone, soon becoming a vertical plate fusing with the ethmoid and inter-orbital septum. Here also the obliteration of sutures is complete. The *vomer* is present but inconspicuous. The *maxillaries* form the sides of the beak and, in connection with the premaxillary, form a continuous bony ceiling to the roof of the mouth, which is covered with a thick horny sheath, so thickened on the edges as to make the knife-like cutting *tomia*. The *palatals* are movably articulated to the edges of the maxillaries by broad bases so that they nearly meet on the median line and reach nearly to the jugal, externally. Posteriorly, the palatals extend into forked processes, making the whole length .40 of an inch. From

this process, which descends below the level of the jugal, a nearly vertical plate extends upward to form a sliding sheath which clasps the *presphenoid* and plays back and forward upon it. The flattened ends of the long (.50) *pterygoids* are fused with these vertical plates by expanded, overlapping plates. There are two curved flanges springing from the point where the pterygoids unite with the palatals. The *ethmo-turbinal* plates are more or less ossified and are seen on either side of the rudiment of the vomer. The pterygoids are stout but very unusually long and, on account of the size and position of the quadrate bones, are quite distant from the basis cranii. Near the point of union of the pterygoid with the quadrate bone, a small hooked process, about .12 long, extends upward from the former bone. What the use or the homologies of these processes may be, we do not know, although they occur in finches and in other birds.

At the posterior of the two mandiblar processes of the quadrate bone is a bone as large as the head of a large pin, but of irregular shape, which may be regarded as either a sesamoid contributing to lock the jaw or an independent portion of the quadrate. There is also a very minute sesamoid at the union of the quadrato-jugal and the quadrate. The lower jaw shows no evidence of its composite character. The whole anterior half is enlarged and forms a simple trough of cancellous bone which may be assumed to consist of the dentary elements of both rami. The surangular, angular and splenial elements of the rami are not distinguishable. The articular portion consists of a huge flange, extending inward and upward and is perforated at the middle of its inner surface for the entrance of Meckel's cartilage.

What corresponds to the surangular portion is a broad triangular plate extending upward inside the jugal bones and serving to further lock the jaw. Thus, as we have seen, the whole skull is modified in harmony with the enormous rhinencephalic development.

The *hyoid arch* is well developed and consists of seven bones, whose homologies, in the present state of our knowledge, cannot be made out. The anterior pair are pointed before and behind and attached at the middle to each other and the end of the azygos bone which next follows. The first mentioned bones are called *entoglossal*, by Gegenbaur, by some American authors, *ceratohyals*, with no real evidence that they are homologous with the bones so called in other animals. The following element may be called *basihyal* (*copula* of Gegenbauer,) and is flattened to form a vertical plate and bears on

either side, posteriorly, the *cornua*, which each consists of one straight shaft, .50 long, and a shorter fusiform segment. Between these the *urohyal* extends backward as a support to the trachea. The atlas and axis are fused together more or less fully. There is no neural spine on the *atlas*, but its dorsal surface is perfectly plane. The *axis*, or second cervical vertebra, has a well developed spine and posterior zygapophyses and also a very large haemal spine, which curves backward. The *third cervical* has a smaller neural spine and its posterior zygapophyses project upward. Its haemal spine (hypapophysis) curves forward. There is a slight inferior lamella of its transverse process. The *fourth cervical* introduces a new type, having a low spine, nearly horizontal posterior zygapophyses, and elongated styloid inferior lamellæ. It has a smaller hæmal spine. The following cervicals have no neural or hæmal spines, the posterior zygapophyses decline, and the styloid appendages are very long. The thirteenth and fourteenth (last) cervicals have *pleuropophyses* (ribs), those of the former being mere rudiments, while those of the latter are large but have no connection with the sternum. These vertebræ, in common with the first of the dorsals, have strong hæmal spines. They also have the *capitula process* well developed to receive the head of the rib. The transverse process has its normal *tubercular facet* to sustain the tubercle of the rib. There are six *dorsal vertebræ*, which are more or less firmly co-ossified. The transverse processes are large and the spines of uniform size. The last dorsal is firmly united with the following nine vertebræ, which form the vertebral framework of the sacrum. Seven free vertebræ follow, forming the free *caudal* series. Each of these has a strong transverse process and a more or less perfect neural spine. Upon the last two there are also haemal spines. The last bone or *pygostyle* is remarkable for the great development of its neural spine.

The sternum is normal for the group and is 1.20 inches long. The keel is well-developed, being .50 high. The mid-xiphoid process is .40 wide at the end. The lateral xiphoids are separated by an excision one half as wide and rather more than .40 deep. The transverse sternal angle (that between the two sides of the body of the sternum,) is sharp and considerable. The costal processes are strong, while the coracoid grooves are .25 in width. The manubrium is particularly large and is bifid. Each of the six ribs, as well as the last cervical rib, has a well developed uncinate process.

The strongest bone in *the shoulder girdle* is the *coracoid*, which is expanded below and obliquely winged for a short distance, then is cylindrical and then curves inward, throwing off a flange-like process where the scapula is articulated, and ends in an articular surface against which the flattened upper part of the clavicle is pressed. From the lower angle of this surface a strong tendon passes to the process of the manubrium on that side. The *clavicles* are of the usual form, forming the merry-thought in connection with the anchylosed interclavicle. The *scapula* is united to both clavicle and coracoid and with the latter furnishes a glenoid surface for the humerus. Between these three bones, at their union, is a cavity, *foramen triosseum*, permitting the passage of the tendon of the sub-clavius muscle.

The *anterior extremity* is of moderate size. The *humerus* is .95 long and is much expanded proximally where it is .33 in breadth. The radial crest is short and quite prominent. The ulnar tuberosity is very large and outwardly presents a large triangular surface and within excludes two extensive fossæ, divided by a strong septum, from the end of which a strong process is developed. The opposite or distal end of the humerus is less highly developed, but still shows a high degree of perfection of the spinous appendages. The trochlea, consisting of the radial and ulnar tubercles, are about as usual. The radial condyle is a small prominence directed forward at the base of the radius, while the ulnar condyle is a larger acute process, extending in the opposite direction. The *radius*, the smaller bone of the arm, is but slightly curved and measures 1.20 in length. The ulna curves considerably, proximally, so that the sigmoid cavity is quite oblique to the shaft, and the olecranon process is small and styloid. The carpus contains two bones which have the usual positions. The *ulnare* is applied to the back side of the ulna and rotates upon its smooth articular surface. The *radiale* caps the ulnar and is overlapped by the radius in front. The three metacarpals are fused at the base. The first one can not be distinguished and its phalanx measures but .20. The second metacarpal is .65 long and is fused at both ends with the slender third metacarpal. The second digit consists of two phalanges, the first of which is .30 long and consists of two bars connected by a thin plate of bone, the second being a triangular plate .15 long. The third digit consists of a styloid phalanx .20 long. (The two ossicles described by Schufeldt, in certain birds, as the *cuneiform* and the *pentosteon*, are not discoverable in any of the skeleta before me.

The *pelvis* is papery and yet very complete. The obturator fissure, separating the *ischium* and *pubic* moiety of the pelvis is divided into an elongated posterior and smaller circular anterior foramen. The ilio-siatic foramen is quadrate, with rounded angles. The pubic bone is produced into a slender curved process, as usual in this group. The femur is .91 long and nearly straight and requires no description.

The *tibia* is a symmetrical straight bone, 1.30 long, while the fibula is nearly free from it and is about half its length. In the skeleta of adult birds, such as those before us, it is useless to attempt to distinguish the tarsal bones which unite with its epiphyses, thus forming the *tibio-tarsus*, nor yet the composition of the succeeding segment of the leg, the *tarso-metatarsus*. The latter is .80 long and is furnished with a strong process ("calcaneal,") behind, which is at present causing so much discussion. The subdivision at the distal extremity into the four metatarsals is distinct. The first of these, the *hallux*, is provided with a separate matatarsal, the *accessorius*, which is quite large and descends to the level of the other united metatarsals. The phalanges of the hallux are two in number, the first being very large, .32 long. The claw borne by the following phalanx is the strongest on the foot. The second toe has three phalanges, the third, four, and the shorter fourth, five, as is the case in all of the present group of birds.

Such a bare description as is above given of points in the osteology of a species of bird, is of little value, except as furnishing a basis for comparison with others of its own and other groups. Such a comparative study we cannot at present attempt, but may, perhaps, profitably note some points of difference between the present species and others of its own family, *Fringillidae*. Quite at the other extreme of the family may be found the genus *Pipilo*, which is represented in our region by the Chewink or Ground Robin, *P. erythropthalmus*, a bird of singular appearance, in some points resembling the Orioles, while mimicking the habits of the Brown Thrush. A comparison with this species then may be expected to give us the limit of divergence in structure within the family, and those points which are identical in both may, with some probability, be assumed to be of family, ordinal or class rank.

The skull is of very different form, but the differences are chiefly those accompanying the reduction in the size of the beak, which in the Chewink is slender, almost Icterine. This slender pointed beak does not extend backward so far as in the true Finches, but

the malar pillar is much longer and the angle of the beak and the end of the tomia are forward from the orbit. The opening of the nares is much larger and the lachrymo-nasal space is a very large triangular opening. On this account the ascending process of the maxillary is quite slender. As seen from above, the skull of *Pipilo* is much narrower between the orbits and the facial portion of the skull is easily distinguished from the cranial. The orbits are rather larger and not nearly as well guarded. The lachrymal is of the same shape, but lacks the long slender process directed backward, below. The lachrymo-nasal foramen is small. The interorbital septum is very poorly developed, two oblong foramina extending longitudinally leave but a narrow bridge between them. The ethmoid is therefore greatly reduced. The back of the skull is alike in both, but the opening of the bullæ is directed more forward. The palatal bones are quite similar, but the posterior processes are not bifid. Two curved slender rods, which seem at least partially ossified, pass from the palatal processes of the maxillary to that part of the palatals farthest forward and highest. The pterygoids are of the usual shape and are flattened anteriorly to slide over the sphenoids. The quadrate is smaller and of the same form, but has a rather longer orbital process, proportionally. The quadrato-jugal has the same hamular process posteriorly as described in the Grosbeak. The lower jaw is, like the upper, rather weak. The various parts entering into each ramus are indicated by the presence of a large oval foramen separating the surangular, angular and splenial, and the flange of the articular is large. The differences in the shoulder and arm are slight and are such as might occur in species of the same genus. The sacrum is relatively much stronger and the spinous armature is greater, this corresponding to the greater demand upon the muscles there finding origin. The foramina are of the same number, but the lower one is more elongated to correspond to the greater development of the pubic bone. The femur is of ordinary form, but the tibiotarsal segment is greatly enlarged. The fibula is quite well developed and is anchylosed with the tibia about one half an inch from the head, for a short distance, but is free above and below. The head of the tibia develops two huge processes and there is a small patella. The condyles are very large. The "calcaneal" process, strangely enough, is very small and poorly ossified. The foot itself is not particularly enlarged.

The form of the sternum is very closely alike in these birds; in

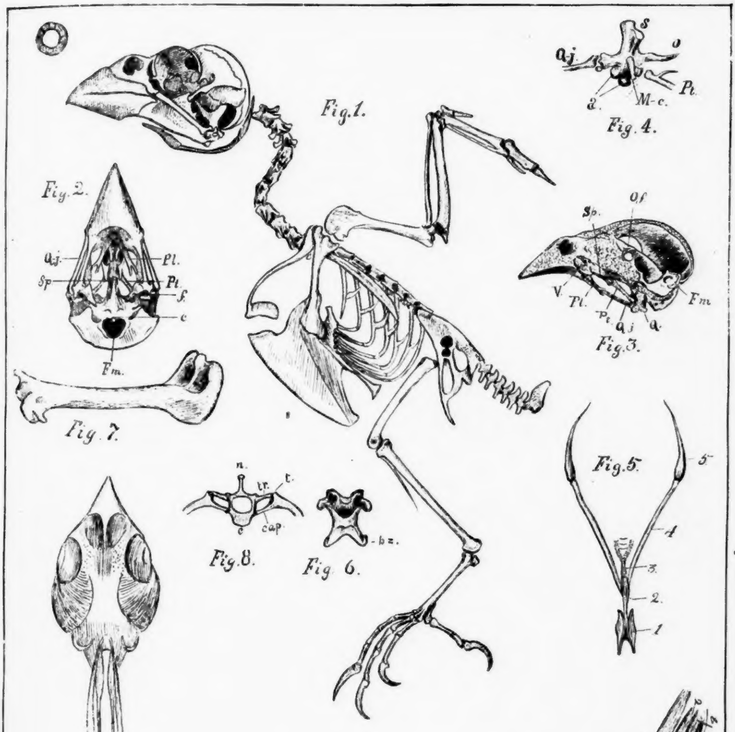


Fig. 1.
Fig. 2.
a.j.
Pl.
Sp
Pt.
f.
c
Fm.
Fig. 3.
Sp.
Of
V.
Pl.
Pt.
q.j.
q.
Fm
Fig. 4.
s
o
a.j.
Pt.
a.
M-c.
Fig. 5.
5
4
3.
2.
1
Fig. 6.
b.z.
Fig. 7.
Fig. 8.
n.
tr.
t.
c
cap.
Fig. 9.
9A
LACH.
FRONTAL
PARIETAL
NASAL
SQUAMOSAL
ETHMOID
A.SPHEN.
PREMAXILLA
MAX.
BASISPHENOID
AUD.
SUPRA-OC.
JUG.
q.-j.
QUADRATE
EX.OC.
STAPES
VOMER
BASI-OC.
I
II
III
PTEREGOID
MECKEL'S CARTILAGE
PALATAL
Fig. 3A.
G.I.H.

fact, the sternum is a valuable osteological index, for, not only is it pretty constant in a given family, but it presents points of constant difference between many families. The manubrium is larger, if anything, than in the Grosbeak.

Such are some of the differences noted between these species and they may be taken as indications of those points in the osseous structure most readily responding to changes in habit or habitation as induced by changes in the environment. It is by the elimination of the variable elements of different degrees of constancy that classification can be placed upon a permanent and correct basis. The variable points may be employed in distinguishing species, genera, etc., in accordance with their relative permanence or value.

PLATE I. *Anatomy of Hesperiphona.*

Fig. 1. Lateral view of entire skeleton.

Fig. 2. Skull seen from below. *Qj*, quadratojugal; *Pl*, palatal; *pt*, pterygoid; *sp*, sphenoid; *c*, condyle; *Fm*, foramen magnum; *L*, internal flange of mandible.

Fig. 3. Transverse section of skull *V*, vomer; *Q*, quadrate bone; *Of*, optic foramen; other references as above. 3*A*, diagram of bones of skull.

Fig. 4. Quadrate bone and articulations. *Pt*, pterygoid; *Qj*, quadratojugal; *a*, accessory ossicles; *m c*, sheath of Meckel's cartilage.

Fig. 5. Hyoid arch.

Fig. 6. Superior surface of a cervical vertebra.

Fig. 7. Humerus.

Fig. 8. A dorsal vertebra, from behind.

Fig. 9. Muscles of the wing seen from above.

Fig. 9*A*. Anterior part of wing from below.

Fig. 10. Skull denuded of skin and showing certain cervical muscles.

II.

METAMORPHOSIS AND MORPHOLOGY OF CERTAIN PHYLLOPOD CRUSTACEA.

[PLATES V—VIII AND PLATE X.]

The group *Phyllopoda* is one of the most remarkable among crustaceans, on account of the peculiar form and life history of most of its members. About the animals of this group there clings a certain air of mystery which may lead one to regard them as almost "uncanny." A pool by the wayside is suddenly formed by a shower and almost instantly becomes populated with a swarm of animal life, which no one ever saw there before and for the like of which we might search an hundred miles in vain. In a few days the little tragedy is played and the uncouth actors have disappeared, no one knows whither, having sown the clay at the bottom of the now dry pool, with eggs which, under favorable circumstances, may again put the play on the boards, but only after being themselves thoroughly dried by the sun. In short, in the study of these animals the unexpected is always appearing and known laws, or at least theories, are again and again negatived. We calmly institute a species when, lo! the change in certain conditions attending the development occasions the change to an entirely different genus in our system.

(See V. Siebold, in *Sitzungsberichte d. math.-phys. Classe zu Muenchen*, 1873, and the paper by Schmankewitsch in the *Zeitschrift fuer Wissenchaftliche Zoologie*, XXV Suppl., 1875.)

In spite of many able papers and works on American Phyllopods (notably the monograph, by Prof. Packard, in *The Geol. Surv. Terr.*, 1868, *Part I*, *Sec.* 2.) many points of deepest interest remain to be cleared up, and particularly such as relate to the development history and homologies of organs. In the present paper a few observations made some years ago, are presented with no attempt to discuss their bearing upon the questions in dispute. The student conversant with the literature of this subject will observe, however, that these facts

make necessary a modification of views at present in vogue in several important particulars. The work was arbitrarily closed by circumstances and the material was long suppressed, in the hope of continuing a study which proved of absorbing interest; but, as this hope is now extinct and no motive remains for further delay, the observations are presented in their necessarily fragmentary form, hoping to fill a place in the life-history of these remarkable animals.

The Phyllopoda are extremely well adapted for use in biological laboratories and the outline here given may make the process of development plainer to the student who is fortunate enough to be supplied with such material for study. The two animals described may be found in early spring and late summer, in many temporary pools throughout the eastern zoographical province of North America.

A. Larval Development of Limnetis gouldii, Bd.

Limnetis is a genus of the FAMILY LIMNADIADÆ of Baird, which includes crustaceans enclosed in a bivalved shell, within which is concealed a body like that of a Water Flea, but having ten to twenty-seven pairs of leaf-like swimming feet. The very large head projects from between the valves in front and is flanked on either side by a biramose second antenna, while the first pair of antennæ is very small. A figure of the adult of the present species will be found in the monograph by Dr. Packard, and also in a paper by the present writer, in the 10th Annual of the Minnesota Geological Survey.

The earliest stage seen (Plate VI, Fig. 2.) was the simple nauplius-form common to all this group of crustacea, but so curiously modified as to at first almost defy recognition. The animal, as viewed from above, seems covered almost entirely by an oval shield, which is thickly studded with spines arranged in anastomosing lines. The head extends into a frontal prominence, which is densely bearded. The posterior part of the body forms a blunt prominence, bearing two spines. The eye, occupying the front of the head, consists of a single pigment fleck, with at first a single lense (?). The digestive tract is simple and similar to that of other Phyllopod larvæ. In the protuberance which represents the future abdomen, the muscles producing the pumping action of the rectum are well developed and anal respiration at once begins.

The appendages differ only in form from those of other larvæ. The antennules are long and curved prolongations of the frontal region

and project laterally. They are covered with a spiny cuticle, like the antennules of the nauplius of *Chirocephalus*, but are less movable and less obviously tactile organs. It has been denied that these are really antennæ, but the history of their further development makes it clear that they are really representatives of those organs, though obscured by their covering.

Although the nauplius of Limnetes is said by authors (Packard, Monogr. Phyllopod Crust, etc.) to be distinguished from other nauplii by the small size of the labrum, this is founded upon a mistake. The labrum is really the most prominent of the larval organs. It is, indeed, of monstrous form and is so enlarged as to become a valve nearly as large as the shield-like expansion of the body above. The larva resembles a small turtle, from the edge of whose shell protrude two pairs of appendages.

The labrum is thorned, as is the whole body, and is slightly, if at all, movable. In this respect it differs little from other young nauplii. Like the first pair of antennæ, the labrum is obscured by its larval envelope, similar to that which extends the carapace of the body to form a false shell. The second antennæ are of the usual form among Phyllopods, the anterior branch being five-, the lower one two-jointed. The basal portion is furnished with a prominence bearing two heavy claws. The palp of the mandible is of the usual form.

In the next stages slow changes accompany the increase in size. A dorsal area is marked off over the maxillary and mandiblar segments, from which the shell develops under the larval covering. The nauplius eye becomes associated with a pair of club-shaped sensory hairs. A ventral swelling becomes distinct and proceeds to segment itself and elaborate limbs. (Fig. 1, Plate VII.) In figure 11 of this plate, which gives a semi-diagramatic under view of the abdomen, is shown that, as in other Phyllopods, the appendiculate segments seem to appear at once and the development goes on then from before backward. Prior to the appearance of feet (stage of Fig. 1.) the animal is about 0.33 mm. long, but becomes over 0.50 mm., before the metamorphosis. In the last stage prior to assuming the characteristics of the adult, the antennules seem smaller, the labrum has become cordate and very wide, while a prominence appears below the eye. Rudiments of the compound eye are visible and the sensory filaments overlying the pigment fleck are developed. The anterior part of the digestive tract has bifurcated and its branches extend toward the labrum.

The accessory branch of the second antenna, with its forceps, has become large. Now the hypodermic contents of the antennules withdraw from its shell and compact themselves into the mature form, developing, at the same time, sensory rods in their substance. The contents of the labrum fall away from the walls and gather into a lobe-like body. Feet have formed, and a single-chambered heart is actively pulsating. The future shell may now be seen under the larval covering, connected only with the back over the segments bearing gnathites, and hanging free about the edges. When the moult is affected the labrum falls within the valves, carrying with it the small tactile antennules, which hang pendant by a slender stalk. The frontal prominence, however, is elongated, forming the beak. The larva is now a diminutive of the adult. In its future development the form elongates and finally again becomes rounded and assumes the familiar appearance. The branches from the stomach fill the front of the head with so-called liver-lobes. The compound eye becomes perfected, while the nauplius eye is covered by filaments charged with some unknown sensory function. The heart becomes multi-chambered and the genital organs appear. For a figure of a young Limnetes, see *Types of Animal Life, etc.*, by the author; for figures of the adult and a discussion of relationships, see Packard's "Monograph of the Phyllopod Crustacea of America"; *U. S. Geol. Surv. of Terr.* 1878, *Part I.*

Farther details may be gathered from the plates. It is a matter of regret that Grube's work on the development of the European *Limnetes brachyura* was not accessable to me during the period which was covered by this paper. My recollection is, however, that the processes are, in the main, identical, but that Grube fails to identify all the organs of the embryo.

B. Post-embryonic Development of Chirocephalus.

The species studied is assumed to be the common *C. holmani*, Ryder, although the oldest male seen differed in several particular from the description of that species. One must imagine a fish-like, transparent animal, about one-half inch long, balancing itself in the water by the movement of eleven pairs of lamellate swimming feet. The colors are brilliant and do not interfere with an almost perfect transparency of the body.

The earliest stage seen is that figured on Plate V, Fig. 1. The animal is at that period .93 mm. long and the antennæ measure about

.57 mm., the antennules .32 mm. The form is that of a nauplius toward the end of its first phase. The antennules are much like those of males of *Moina*, being curved abruptly near the middle. They are clothed with a spiny larval integument, which disappears in the next stage. The sensory ganglia in the end and the connecting nerves are present; of the latter there seem to be two bundles having a different course. The larval eye in the middle of the head is distinct and has two lenses, or, rather, crystalline bodies.

The antennæ are of the form usual to larvæ of this family, the rami being unequal, the shorter being very indistinctly two-jointed, the longer eighteen-jointed. Near the base a small prominence bears long spines, later to serve a temporary purpose in bringing food to the mouth. The mandiblar palp is indistinctly 6-jointed, the inner ramus of this limb, or mandible proper, has a single spine.

The thoracic segments are already indicated and rudimentary limbs lie under the larval skin. The abdomen bears two styles, and has a set of muscles adapted to produce anal respiration in the rectum. The stomach is simple and glandular. Although no heart could be distinguished, blood corpuscles crowd the antennæ and other parts of the body, (see figure 4.) Rudiments of the compound eyes are seen on the sides of the head where pigment is collected.

In the next stage the animal may be .98 mm. long (Fig. 2.) and several changes appear. A well marked scutum covers the mandiblar and maxillary segments. The antennules have lost their spiny covering and the proportions of the antennæ have changed. At the base of the antennæ certain organs develop, which present great resemblances to the branchial sacs of the other feet, but which become the shell-glands of the adult. This is parallel to the like origin of these organs in copepods, as we have demonstrated in Diaptomus. In *Limnetes* it was impossible to follow the development of the shell-gland. (See figure 6, *o*, shell gland; *M*, mouth; *L*, labrum; *Md*, mandible; *Mx*, maxilla; *Mx 2*, second maxilla.) The brain lobes or supra-œsophagal ganglia resemble those organs in cladocera, the optic-lobes being apparently hollow, however. The posterior part of the body is now considerably elongated. The segments of the thorax seem to be all differentiated at once and the segmentation is obscured by a false segmenting of the posterior part of that region or the apparent absence of segments. The region about the rectum is open and crossed by the muscles giving it motion. It frequently seemed to me

that this chamber was that in which the blood-corpuscles (or, better, lymph-cells) were formed. The rectum is covered with irregular masses of cells of varying size, and I more than once thought to have observed their change to lymph-cells. It was impossible, unfortunately, in the time allotted to observe the development of the circulatory system, but it would seem that the heart differentiates from the connective tissues between the stomach and the scutum.

(Fig. 3 illustrates not only the formation of the posterior appendicular segments, but the rectal sinus with its muscles and lymph-cells. A simple valvular apparatus separates the rectum from the anterior part of the digestive tract.)

The next stage is illustrated on Plate VI, Fig. 1. A change in proportion and in size is all that requires notice. Figures 3–6, illustrate the growth of the appendages. Fig. 3 is the first foot of the right side of an individual over 1.5 mm. long. Fig. 4 is the same of a younger individual of which Fig. 5 is the sixth and Fig. 6, the ninth foot. Fig. 7 shows how the matrices of the caudal spines are developed from enlarged cells as are the corresponding parts in Daphnia.

Fig 2, of Plate VII, illustrates the general characters of the animal when about 2 mm. long. The maxilla have become larger and the feet begin to assume their definitive form.

Fig. 3 shows the growth of the caudal stylets and the character of the valve at the opening of the anus, as well as the prolonged matrix at the setæ. Fig. 4 illustrates the differentiation of the optic lobes and of the anterior part of the stomach. The heart is by this time well formed and whatever part the rectal cells may have played in originating lymph-cells, is lost. The liver lobes grow out from the stomach and the labrum becomes reduced. The antennæ now undergo a rapid and remarkable transformation. In the male the shorter ramus becomes atrophied as shown in Fig. 10, and from the base an epipodal body is formed just as in the case of the feet. At first this pouch resembles homologous organs in the feet, but soon it alters and becomes greatly modified. In the female the change is similar, save that this branchial sac fails to develop (Fig. 9.) The palpus of the mandible is likewise reduced to a mere rudiment (Fig. 8.)

The sexual organs of the female appear as lobed glands (Fig. 12.) The caudal stylets are of considerable size. A male, in the stage above mentioned, measures 3.5 mm. In the following stages growth is rapid. The antennæ modify rapidly.

Figs. 2 and 3, of Plate VIII, show the form of the antennæ of the female and male in this stage, the former being .78 mm., the latter .79 mm. long. In the male the palp is gone and the appendage is considerably developed, the longer ramus still showing its primitive form. Fig. 4 figures the fourth foot of a male 3/8 inches long. Fig. 5 shows the abdomen of a larger male, and Fig. 6, the stylets when they are .78 mm. in length. Fig. 1 shows the form of the head of a male some time prior to maturity, and Fig. 8 illustrates the external genital organs of one side at the same period. The testis, only part of which is shown, is a double chamber. The penis is paired and each factor is spiny. A common muscle protrudes them both by lateral pressure, while a muscle peculiar to each serves as a retractor. Fig. 7 illustrates the form of the male antenna, previous to the branching of the so-called frontal organ. As to the homologies of the "frontal organ," there is no doubt that in Chirocephalus, as stated many years ago, it is an appendage of the base of the antenna and the development shows it related in position and formation to the branchial sacs of the other limbs.

There is a curious dimorphism among these animals, as in copepods. The males, under certain circumstances, become sexually mature, while the antennæ retain an undifferentiated character. The antenna in this stage, has a short basal process and the remainder is rather short and bifid at the tip, one of the branches bearing a sharp spine. The frontal appendage is simple, coiled, and regularly crenulate in this stage. The next stage is characterized by the elongation of one of the short branches at the end of the male antennæ and the modification of the frontal organs.

Explanation of Plates.

Plate V.

Fig. 1. Young nauplius larva of *Chirocephalus*.

Fig. 2. The same in an advanced stage.

Fig. 3. End of body of individual of same age as figure 1, showing cavity about the rectum and its muscles, the cells springing from the walls of the rectum, the blood corpuscles, the valve at the posterior end of the stomach, and the primitive segments outlined in the cellular mass.

Fig. 4. End of the longer branch of the second antennæ, with massed blood corpuscles.

Fig. 5. Mandible and palpus.

Fig. 6. Lower view of anterior part of a larva, about the size of that shown in figure 2, *oc.* nauplius eye ; *A1*, antennæ ; *e*, eye ; *g*, upper ganglion ; *g1*, optic lobe ; *A 2*, swimming antennæ (base only shown); *M*, mouth opening, bordered on either side by commissures passing to the infra-œsophagal ganglion ; *L*, labrum ; *Md*, mandible and palp ; *Mx*, first maxilla ; *Mx 2*, second maxilla ; *I, II, III, IV*, etc., feet in different stages of development.

Plate VI.

Fig. 1. *Chirocephalus* larva in an advanced stage, seen from above.

Fig. 2. *Limnetes gouldii*, early stage.

Fig. 3. First right swimming foot of *Chirocephalus* when 1.4 mm. long.

Figs. 4–6. First, sixth, and ninth feet of younger larva.

Fig. 7. Abdomen of same.

Plate VII.

Fig. 1. Larva of *Limnetes* .33 mm. long. *A*, first antennæ ; *A 2*, swimming antennæ; *Md*, mandiblar palp . *e*, eye ; *l*, lense ; *L*, liver, budding from anterior part of stomach ; *s*, sensory filament ; *m*, muscles of rectum.

Fig. 2. Larva of *Chirocephalus*, from below.

Fig. 3. Caudal stylet of same.

Fig. 4. Head, showing organs of one side, *L*, liver.

Fig. 5. Muscles of swimming antennæ.

Fig. 6. Maxilla. *Fig.* 7. End of abdomen of an older individual. *Fig.* 8. Mandible and palpus (*p*) in this stage. *Fig.* 9. Antennæ of female. *Fig.* 10. Antenna of male ; *p*; inner ramus ; *g*, frontal organ.

Fig. 11. Part of *Limnetes* older than figure 1.

Fig. 12. First abdominal segment of female, seen from below.

Plate VIII.

Fig. 1. Head of male approaching maturity.

Fig. 2. Antenna of female, (length of antenna .78 mm.)

Fig. 3. Antenna of male of about the same age, (length of antenna .79 mm.)

Fig. 4. Fourth foot of male 3/8 inches long.

Fig. 5. Abdomen of young male.

Fig. 6. Caudal stylets of same, (.78 mm. long.)

Fig. 7. Antenna of same.

Fig. 8. Copulatory organs of one side, *m*, muscle common to the sheaths of both male organs ; *p*, penis or forceps ; *t*, testis.

Fig. 9. End of sensory antenna ; *a*, sensory rods, enlarged.

Fig. 10. View of the surface of the basal knob on the male antenna.

Fig. 11. Larva of Limnetes when .5 mm. long, showing withdrawal of the hypoderm and its contents from the walls of the antennules and labrum. *A*, antennules inside the sheath formed by their old covering. *L*, labrum inside its old shell, *L*1.

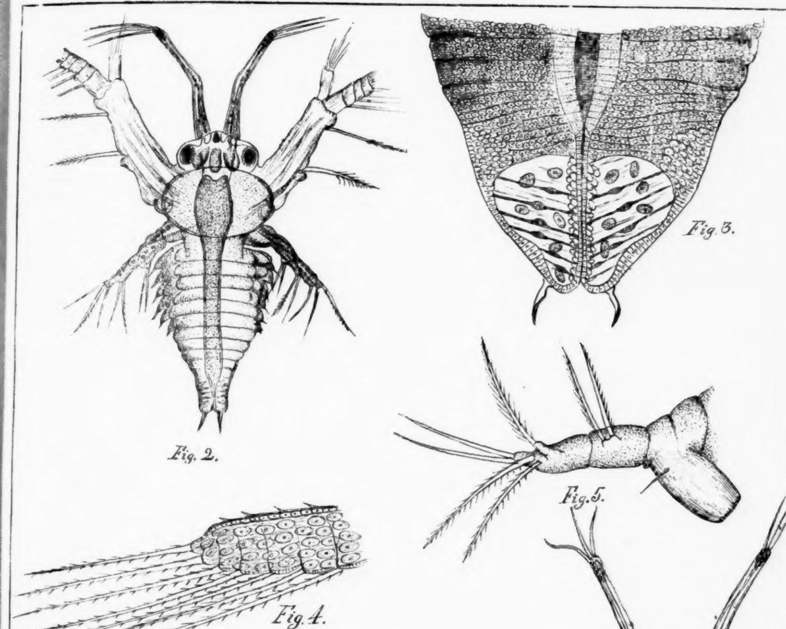
Plate X.

Fig. 1. Head of *Chirocephalus*, male, nearly adult.

Fig. 2. A typical foot of the same.

Fig. 3. One of the swimming feet of *Limnetes*.

Fig. 4. Outline of the head of *Limnetes*, after the metamorphosis, showing relation of labrum and antennules and also the position of the beak, eye and sensory fleck.



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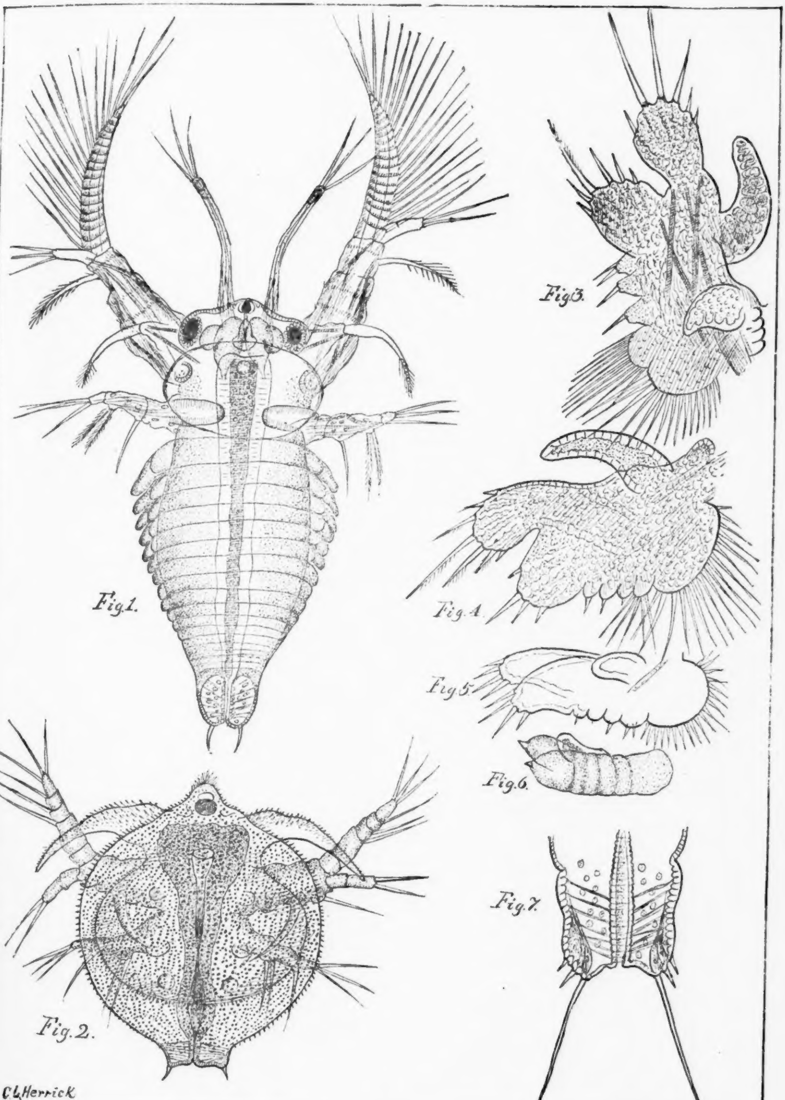
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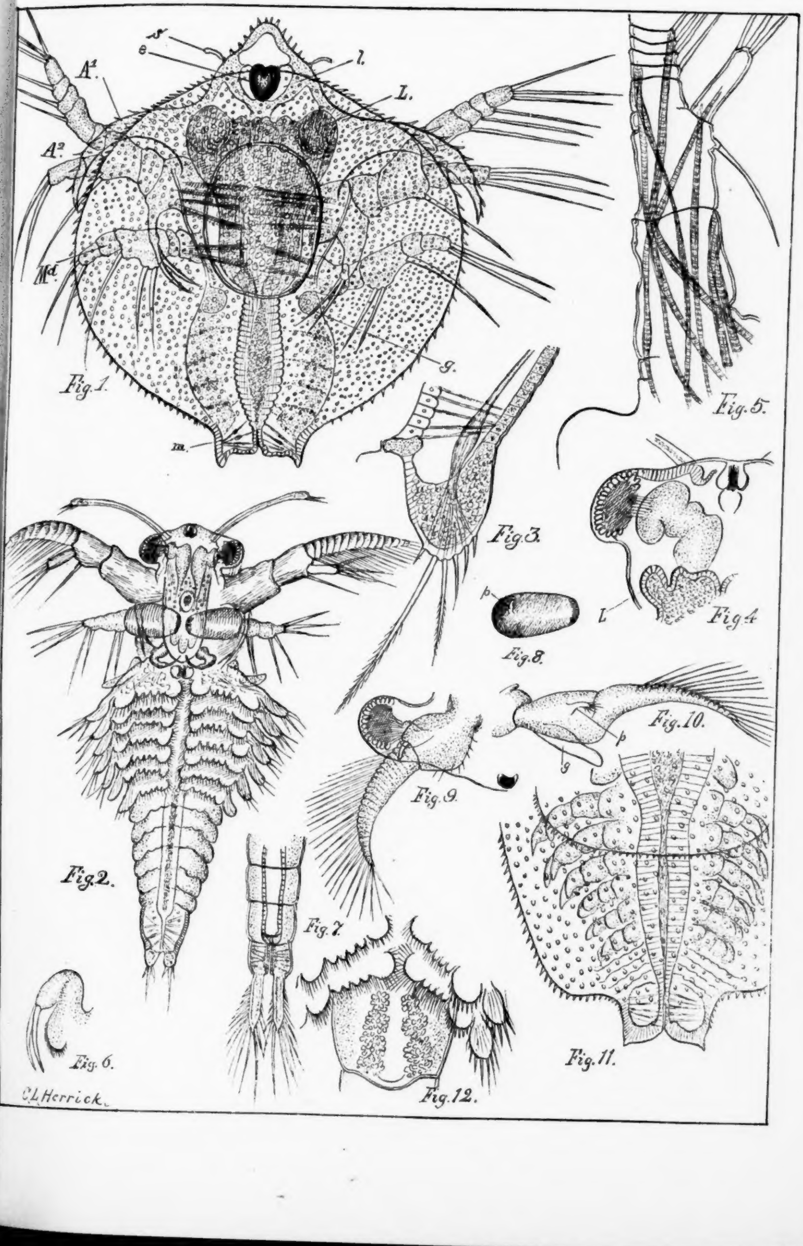

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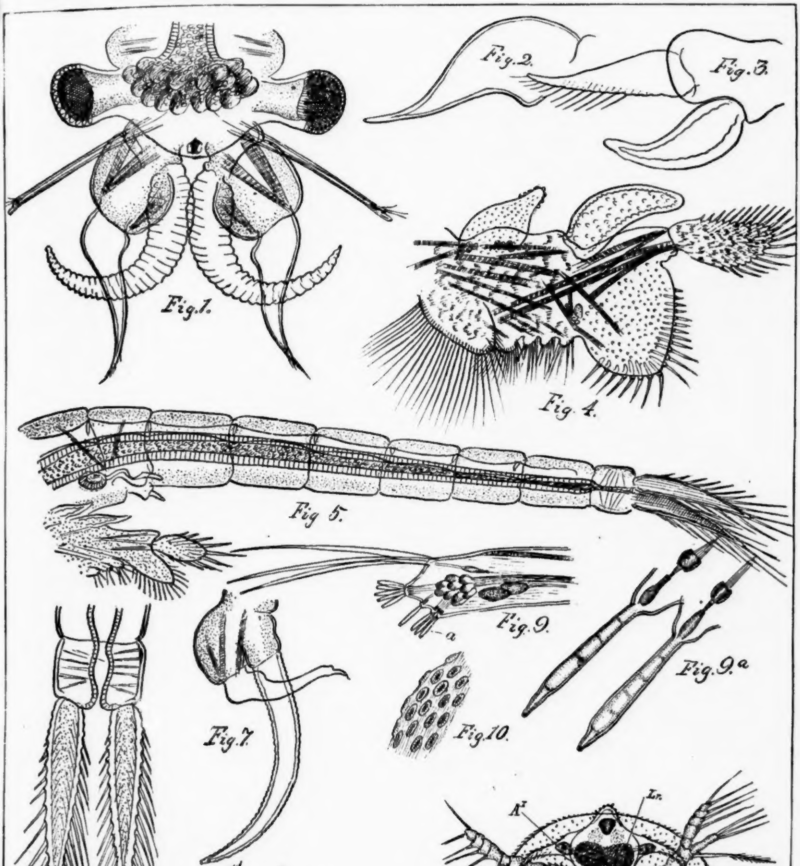
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III.

SUPERPOSED BUDS.

Plate XII.

BY A. F. FOERSTE.

Buds are usually produced singly in the axils of leaves. When more than one bud is found in the same axil, the additional buds are *accessory* and *supernumerary*. When they are placed at the side of the one immediately in the axil, the buds are *collateral*, when placed in a line vertically above the axillary bud, the additional buds are *superposed*.

Accessory buds are not of the same age. In the case of collateral buds, the one immediately in the axil is the oldest. Among superposed buds there are two methods of development. The axillary bud first produced becomes visible, grows, and may reach some size before any additional bud is apparent. After a time another bud appears immediately above the one already produced. A third or fourth bud may appear above the one last formed. In the Tartarean honeysuckle (7) four or five buds are occasionally found arranged in such a series above the true axillary bud. This is called *direct* superposition and is of rare occurrence both among woody and herbaceous plants.

Usually, however, the axillary bud first produced reaches a considerable size before a second bud appears. This second bud is inserted beneath the one first formed. If the second grows rapidly enough, a third bud may appear beneath the second, and a fourth beneath the third. This is *inverted* superposition and is very common indeed, both in ligneous and herbaceous plants. In several species of the *Juglandaceae* and in *Gymnocladus Canadensis* (6) where the buds do not immediately follow one another but are arranged at short intervals along the internode, five or six buds are occasionally found superposed in this manner. The upper buds here betray their earlier origin by their greater size and development.

In both direct and indirect superposition the bud first formed is the largest, the best developed, and the one most likely to grow and to form a branch. If several buds produce branches, those from the later buds are successively smaller. If the largest and earliest bud dies, the next in age takes its place and produces the branch. Insects frequently cause the death of branches; early frosts may nip the tender shoot; birds, squirrels and other animals frequently feed upon the buds themselves; in all these cases the smaller, more undeveloped buds may come into play and be called upon to continue the life and growth of the plant. Superposed buds are thus a provision of nature to remedy the loss of buds or branches, however occasioned. Buds are usually formed a short time after the tissues of the leaves have become differentiated from the stem, and the ordinary scaly buds of ligneous plants can be seen in a rudimentary condition almost as soon as the leaves can be distinguished by the naked eye. By the time the leaves are fully developed the scaly buds have also reached a stage bordering on maturity, and this generally before the middle of summer. Between this time and autumn they undergo a slow change and induration which prepares them for winter. Superposed buds of the same axil originate at different times, but the bud first formed develops subsequently to the formation (differentiation) of the subtending leaf. The difference in time in the appearance of the several buds is sometimes very slight, so that they seem to originate almost simultaneously. This is true of *Gymnocladus*, in which, however, the difference in size is well marked at an early period.

Superposed buds do not appear in all the axils of a plant; it is even uncertain whether they can be found in all individuals of any single species. Nor do they always appear in equal numbers. The existence of accessory buds is a sign of vigor; the leaf-axil does more than the normal amount of work whenever it produces more than one bud. The period of greatest vigor and most rapid growth is not when the plant is small and struggling for life, but when it has reached some size and has abundant roots. Accessory buds in herbaceous plants are usually found, therefore, in the upper axils of the plant, and, if more than two buds be found in any of the axils, the greatest number will be found in the most vigorous axils. But these are not the axils last produced, because at this time of a plant's history the flowers are being formed, a period just preceeding the plant's maturity and decay, when there is not much need for accessory buds, unless it be to con-

tinue the inflorescence, as in species of *Lactuca* and *Delphinium*. Besides, at this time the rapid production of blossom and fruit seems to exhaust the vital powers of the plant. Hence, accessory buds are usually found in greatest abundance above the middle of herbaceous plants, but not at the very tips of the branches.

With ligneous plants it is different. Each year's growth may be said to repeat the life of the tree, and the twig takes the place of the entire herbaceous plant. The period of greatest vigor in an ash twig is not when the sap has begun to flow and the leaves have barely seen the sunshine, but when most of the leaves have opened out their blades and are in full operation. It is the time when the upper part of the twig is developing. In the ash, where the terminal bud is already produced in June, the leaves last formed subtend accessory buds, while those formed earlier usually subtend only the single axillary bud. In young, vigorous shoots of hickory and walnut, the axils first formed contain a single bud; those towards the middle of the branch, two buds, one of them accessory; the axils later formed, from three to four buds; and in very vigorous branches the last formed axils may contain even five buds. Many trees which usually do not form accessory buds (*Fraxinus Americana*) (1) produce large and well developed ones in all the upper axils, when the tree has been cut down and the strength of all the roots is turned to the support of a few fresh shoots growing out from the old stump.

The term *superposed* buds was introduced to explain the existing state of things in ligneous plants, where they were first studied. Here the buds are really placed one above the other along the internodes of the plant, and frequently by the lengthening of the internode during the earlier part of its growth, the buds may be considerably removed from one another and the uppermost bud may be about an inch above the lowest, as in the *Juglandaceae*. In such cases the earlier and hence upper buds, being separated while the twigs were growing most rapidly are further removed from each other, than the lower buds, which grew during the less vital period of the twig's development.*

In *Aristolochia Sipho* (8) this superposition is less evident, for here the buds are arranged at about the same height in the leaf axil, so that superposition exists only hypothetically. Although evidently super-

*The separation of superposed buds, caused by the varying growth of the internodes, was noted several years ago by Mr. W. B. Werthner, who first called my attention to it. A. F. F.

posed buds are occasionally found among herbaceous plants, in the far greater number of cases they are inserted at about the same level and superposition can only be morphologically asserted from the evident origin and development of the buds. Ligneous and herbaceous plants are almost directly opposed to one another as to the character of their superposition.

Again, while in ligneous plants the superposed buds are usually found during their first season as buds, in herbaceous plants one or more buds are immediately developed into branches. Since the aerial portion of herbs in our climate is destined to decay at the approach of autumn, and sometimes even before that season arrives, buds do not long remain in a rudimentary and inactive state, but grow rapidly and form branches and flowers. The first formed bud in an herb is therefore unusually a well developed branch before the second bud in the same axil becomes visible to any but the careful observer. In some plants at this period the petiole of the subtending leaf must be carefully removed and the lower part of the developed branch closely examined in order to find the flattened bud lying closely against it. Some of the small buds later in the season turn into branches and even bear flowers, but most of them will never develop unless some accident should befall the branch already formed.

Whenever the phyllotaxy of the branch bearing superposed buds is that of decussating pairs of leaves, the lowest pair of bracts or leaves of each axillary member is always placed transversely to the stem and its subtending leaf. The lowest pair of leaves or bracts are therefore similarly inserted in all members found in the same axil. In members which belong to plants having a spiral arrangement of leaves, the lowest bract or leaf in all specimens examined was placed towards the left or right of the subtending leaf, *i. e.* transversely, but not always on the same side. Members of the same axil may have an insertion which places the first bract or leaf always on the same side of the stem, or they may be regularly opposed to one another, or there may be no definite arrangement whatever in this respect. The same thing may be said about corresponding members of different axils.

A form of superposition occurs in some herbaceous plants which seems to occupy a middle ground between superposed and collateral buds. In *Thalictrum dioicum*, for instance, the oldest bud or branch is nearly in the axil of the subtending leaf, then by means of inverted

superposition follow three or four other buds or branches, not in a straight line, but placed alternately towards the right and left of such a line. The insertion, therefore, is similar to the arrangement of the uniparous scorpioid cyme. But, aside of mere appearances, there is no reason for considering them as anything but cases of superposition in which the different members of the same axil have alternately been thrown towards opposite sides. It is worthy of notice that this form of superposition is common among certain species of *Leguminosae* (*Medicago*), where the ordinary forms of superposition are also abundant both among herbaceous and ligneous plants.

Another form of superposition is very common in species of *Solanaceae*, where the main axis ends in a flower or inflorescence, which is cast to one side by the first formed axillary bud. This bud grows into a branch and continues the main axis, taking an erect position and seeming to be its direct continuation. The leaf which subtends this branch usually contains a bud which is morphologically the second-formed bud of the axil. Eichler figures in his "Bluethendiagramme" two of these accessory buds in the leaf axils of *Atropa Belladona*.

And, finally, since flowers, thorns, tendrils, and other organs are frequently the morphological equivalents of buds, they will often be mentioned in speaking of superposed buds.

In the following pages an enumeration will be made of such plants as will illustrate the general remarks made above, and any details not hitherto mentioned will be made under the particular species when cited. In these notes most attention will be paid to herbaceous plants, since less attention has been given to these, and they present some variations not noted in ligneous plants.

I. INVERTED SUPERPOSITION.

A. Of Leaf-buds and Branches.

1. BUDS.—The superposition of buds, none of which have developed into branches, occurs chiefly among ligneous plants. *Fraxinus sambucifolia*, *F. viridis*, and vigorous specimens of *F. Americana* (1) have two buds in the same axil, placed close together, the lower about half the size of the upper. *Cercis Canadensis* shows two or three, the lowest of these often minute and somewhat covered by the petiole scar. *Ptelea trifoliata* (14) has also two superposed buds. In this case they are sunk into the wood and almost inclosed by the crescent- or almost V-shaped petiole-scar, so as not to be evident. *Carya*

alba (2), *C. sulcata*, *C. tomentosa* and *C. porcina*, all have the upper one of the two superposed buds so excessively developed, that the lower remains quite insignificant, often obsolete. *C. microcarpa* and *Juglans regia* have the lower buds of larger size. *Robinia Pseudacacia* has two superposed buds, both of which often develop, but the upper one outgrows the other. In this species the buds are formed beneath the surface of the petiole scar, so as to be invisible until growth begins in spring. Sometimes three buds in one row are seen bursting through the scar which has encased them all winter. *Menispermum Canadense* (17) has also two or three buds covered by the circular petiole scar, through which they burst in spring. Two of three buds often develop into branches. *Gymnocladus Canadensis* (6), which has buds enclosed by circular pit-holes in the bark, frequently presents four or five of these to one axil, the lowest being reduced to a mere dot. The upper two are always quite a distance apart--the lower ones less so. *Sambucus*, which is usually credited with the existence of buds inversely superposed, presents a poor case in *S. Canadensis*, in which the lower buds seem to develop from the upper, and not to be independent of it.

Various species of *Rubus* also show superposed buds having the general aspect of those of *Sambucus Canadensis*. In some species which usually produce three or more buds in the same axil, the uppermost bud is greatly developed and often supported by a basal internode one-eighth to one-half an inch in length. *Carya olivaeformis* (3) has two or three buds, the upper two well developed and some distance apart. The support of the upper is small, often obsolete. *C. amara*, with two or three buds placed closer together, has a support for the upper bud, often one-third of an inch long. In *Ptero-carya Caucasica* (15,) we find the extreme in length of the support–one-half to three-fourths of an inch. Three buds are normally produced in the same axil. *Liriodendron Tulipifera* has three buds close together, the upper with a support often half an inch long. These species offer a sort of transition to those in which the upper bud develops immediately into a branch.

The only case among herbs, known to me, which would properly fall under this class, is that of *Dicentra Cucullaria* (9). The grains clustered about the roots of this plant are known to be either the bases of aborted leaves, or the true bases of the leaves themselves. Both kinds of grains, when sufficiently developed, will

show, on examination, a narrow slit along their upper surface. In this are found one or two buds, of which the one nearest the stem is the oldest and largest. They form an interesting means of comparison with the specimens already noted. Like these, the buds are destined to outlive the winter and begin fresh growth with the opening spring.

2. Buds and Branches.—Species in which the uppermost superposed bud immediately develops into a branch, while lower ones remain for a longer or shorter period in the bud state, are rare among ligneous plants, while among herbs they comprise almost all known cases. In *Cornus stolonifera* (4), a shrub or small tree with two buds to the axil, the upper may develop into a branch some inches long before the season closes, or it may remain only a bud. In either case the lower bud remains small.

The first formed bud in herbs is usually a well developed branch before the second becomes visible. The petiole must often be carefully removed and the lower part of the developed branch closely examined in order to find the flattened bud lying closely against it. This in the month of July is true of *Barbarea vulgaris*, *Sisymbrium officinale*, *Oenothera fruticosa*, *Nesaea verticillata*, *Ambrosia artemisiaefolia*, *Scrophularia nodosa*, *Mimulus ringens*, *Gerardia purpurea*, *Ruellia ciliosa*, *Verbena stricta* (12), *Verbena urticifolia*, *Phryma leptostachya*, *Lycopus sinuatus*, *Teucrium Canadense*, *Chenopodium album* and many others.

Some of these smaller buds later in the season turn into branches. Even in July *Ambrosia trifida* has most of its upper axils filled with two well developed branches. In *Lactuca Canadensis* the younger branch already bears flower buds; the older branch is in blossom. *Brassica nigra* has the flowers of the older branch turned into seed, while the younger one in the same axil is flowering. In *Lysimachia ciliata*, the younger branches are partly in bud, partly in flower.

As examples of plants bearing more than two buds in the same axil, may be mentioned *Chelidonium majus* (10), which occasionally has three such buds, and *Thalictrum dioicum*, which has four or five. In *Ch. majus*, the base of the leaf and node swells and forms a *pulvinus* or cushion, extending horizontally from the stem, and supporting the buds and branches. Since these are borne on the same horizontal plane the term superposed is correct only theoretically. *T. dioicum* will be described later.

B. Of Inflorescences and Flowers.

1. INFLORESCENCES.—*Lippia lanceolata.*—A peduncle, bearing a head of flowers, is superposed to a tiny bud, which, however, does not always appear. *Dianthera Americana* presents the same features. *Delphinium consolida.*—Both the flowers composing the terminal racemes and the upper branches may be found late in the season superposed to axillary buds. The buds found along the lower parts of the racemes, and most of those in the leaf axils generally develop and flower before the season closes. *Lythrum alatum.*—Flowers said by Gray (Man. 183) to be solitary in the axils of the upper leaves. Occasionally, however, they are arranged in cymes of two or three flowers each. In this case two cymes of an equal number of flowers may be superposed to one another; or the lower cyme may be reduced to two or even one flower; single flowers are also found superposed to one another. The place of the lowest flower may even be supplied by a leaf branch which then grows vigorously and bears flowers in its turn—thus a small flower may be seen superposed to a vigorous branch. Branches in this situation occur irregularly along the flower-bearing axes of vigorous plants. *Chelidonium majus* (10).—The main stem here frequently terminates in an umbel of flowers. The bud first produced also develops into an umbel. The next bud may develop into a leafy branch and throw the two umbels to one side and place itself in the continuation of the stem. The last bud, if formed, usually remains small. *Cassia Chamaecrista.*—The raceme of flowers is found at some distance, sometimes half an inch, above the axil. Within the axil is frequently found a branch which may grow and give rise to flowers in its turn. *Penthorum sedoides.*—The lower flowering branches are found in the axils of leaves, but become more and more raised above the axils by adnation to the stem as we approach the top of the plants. The uppermost branches, bearing the immediate inflorescence, all become adnate to the stem, thus forming a single compound inflorescence, the lower members of which are raised far above the subtending leaves, while the upper members may be referred to the axils of some of the tiny bracts scattered about the common peduncle, formed by the union of the flowering branches. Some of the last members of a large inflorescence can not be referred to the axils of either leaves or bracts with certainty. Immediately in the axils of the leaves, whether containing branches in the very axil or removed to a position above it by adnation, may be found a tiny bud,

which never, or at least rarely, develops into a branch. *Lindera Benzoin* (5).—This shrub may have in the same axil either two ordinary leaf-buds, or a leaf-bud and a tiny branch, or two tiny branches. These branches bear a terminal leaf-bud and one or two axillary flower buds just beneath it, subtended by bracts. *Juglans cinerea* and *J. nigra* produce from two to five buds in the same axil, which in the latter species are found closer together. In older trees one or more of these buds develop into the sterile catkins.

2. FLOWERS.—Since flowers are also the morphological representatives of branches, and hence of ordinary leaf-buds, a few species may be mentioned in this connection.

A sort of intermediate condition between flowering branches and flowers are those in which the flower peduncle bears a single leaf-like bract. *Lilium bulbiferum*, to be described later, is such a case. *Aristolochia Sipho* (8) is another. The latter has three or four superposed buds, of which the upper are the strongest. They are during the first season almost enclosed by the base of the petiole. The upper bud, sometimes the two upper buds, are leaf-buds, the remainder being flower-buds. All develop during the following season. The cases of *Delphinium* and *Lythrum* have already been described. *Lindera Benzoin* sometimes belongs here. *Lysimachia nummularia* frequently shows small buds just beneath the flower peduncles, which, I suppose, occasionally develop into leaf-branches. Various foreign species of *Loranthaceae* are known to contain one or more vertical rows of superposed flowers in the axil of the same bract. The flowers, however, are all sessile in these cases.

C. *Other Morphological Equivalents of Branches or Buds.*

1. THORNS.—*Gleditschia triacanthos* also bears a superposed bud, developed in this case into a many spined branch or thorn. Each spine of this thorn is subtended by a small scale, representing a leaf. Below in the axil of the subtending leaf may be found three or more buds, also in superposition. The thorn is usually found removed quite a distance from the leaf axil to which it belongs. The place of the scale in this thorn is often supplied by the leaves themselves.

2. BULBLETS.—*Lilium bulbiferum.*—A peduncle, bearing a leafy bract and a flower, is here superposed to a bulblet immediately in the leaf axil. This bulb may have accessory collateral bulblets on either side.

D. Irregular Superposition.

I. SYMPODIAL GROWTH.—Those species of plants, especially common among *Solanaceae*, in which an axillary branch continues the stem of the plant while another bud is formed in the axil of its subtending leaf, have often been made the subject of special investigation and can be studied in books especially devoted to this subject. The *Vitaceae* among ligneous plants present cases in some respects similar to these. They are all caused by *sympodial* growth.

II. ZIG-ZAG SUPERPOSITION.—Scarcely any other term will express the arrangement of the superposed branches and buds of the plants in question. In *Thalictrum dioicum* the branches will be found thrown alternately towards the right and left of a true median line. The superposed buds, both leaf- and flower-buds, of *Aristolochia Clematitis* will be found arranged in a similar manner. *Atriplex patula* shows the same manner of arrangement. (See Eichler, Bluethendiagramme, II., pp. 83, 533 and 159.) Various species of *Leguminosae* present the same or similar features. In their case the interest is so much greater, on account of the ordinary forms of superposition common to both the ligneous and herbaceous plants of this order. Thus, for example, in *Melilotus alba* the buds are thrown alternately towards the right or left of a true median line, and even where only two buds are found and where crowding is not so evident the same features still present themselves. In closely related species of *Trifolium*, however, the superposition is of the ordinary kind.

II. DIRECT SUPERPOSITION.

Lonicera Tartarica (7). Two to five buds are here superposed. The one directly in the axil is formed first, and those above at successively later periods. The lowest bud is the strongest and generally produces the branch, but occasionally several of them develop. Among flowering branches, the lowest buds produce the flowers, or flower-clusters. *Coreopsis tinctoria* (16).—The upper leaf axils contain a flowering branch, superposed to which is a small bud which later in the season produces two or three leaves and a flower. *C. tripteris* has larger and more developed superposed buds, the upper of which bears leaves and two or three flowers. The superposed branch is inserted, as in the first, directly between the axillary branch and the stem. *Passiflora lutea.*—Immediately in the axil is a tendril which represents

the first bud. At either side of the tendril, representing its branches, is a flower. Above the tendril is found a bud, the undeveloped superposed branch.

(In a curious specimen of *Ulmus fulva* (11), found near Dayton, there were two leaf scars, the places of attachment of two leaves, which supported but one bud, the normal arrangement of the remainder of the branch being otherwise preserved.)

EXPLANATION OF PLATES.

Plate XII.

SUPERPOSED BUDS IN—

Fig. 1. *Fraxinus Americana, L.*, from a one year old shoot growing out of the stump of a tree cut down during the previous year.

Fig. 2. *Carya alba, Nutt.*, the tip of a branch.

Fig. 3. *Carya olivaeformis, Nutt.*, section of a node taken from the upper part of a twig.

Fig. 4. *Cornus stolonifera, Michx.*, A, section of a node showing the contents of only one leaf axil. Twig collected in autumn, showing one of the superposed buds partly developed. B, diagram of buds as they appear in less vigorous axils.

Fig. 5. *Lindera Benzoin, Meisn.*, superposed branches composed in each case of a terminal leaf-bud, and two lateral flower-buds.

Fig. 6. *Gymnocladus Canadensis, Lam.*, buds enclosed in pit-holes.

Fig. 7. *Lonicera Tartarica, L.*

Fig. 8. *Aristolochia Sipho, L'Her.*, a regular leaf-branch represents the first formed bud of last year; the flower, the second bud. B, diagramatic section, showing the buds still undeveloped.

Fig. 9. *Dicentra Cucullaria, D C.*, A, section of a grain. B, slightly enlarged portion of the same, both sections magnified.

Fig. 10. *Chelidonium majus, L.*, A, the main axis is here turned into an umbel of flowers, the first developed bud is in the same case, the second bud is a leaf-branch, the third is still in the bud state. B and C, diagrams showing the relative insertion of branches and leaves. D, a case of superposition with two of the buds developed into leaf-branches.

Fig. 11. (*Ulmus fulva, Michx., a freak of nature, two leaves subtending one bud.*)

Fig. 12. By mistake marked 2 in the lower part of the plate. *Verbena stricta, Vent.*

Fig. 13. *Ambrosia artemisiaefolia, L.*, the first bud has here developed into a leaf-branch ; the second, into an inflorescence.

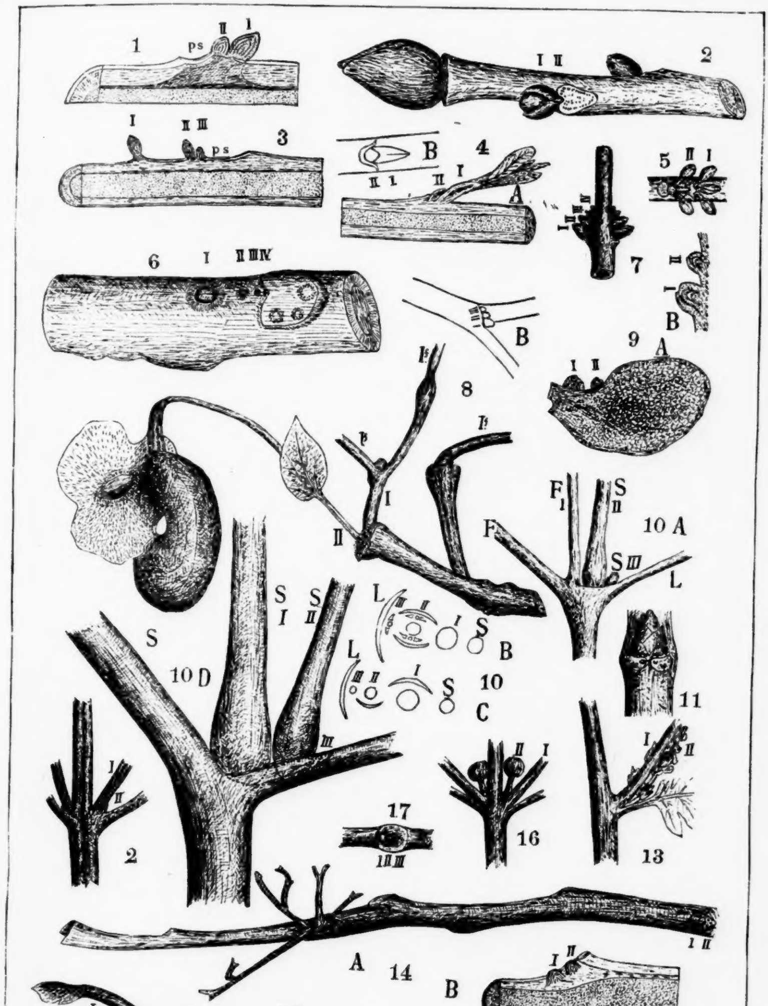
Fig. 14. *Ptelea trifoliata, L.*, A, a case of "Uebergiphelung". B, enlarged section of a node of the same twig.

Fig. 15. *Ptero-carya Caucasica.*

Fig. 16. *Coreopsis tinctoria, Nutt.*, the first bud developed into a flowering branch ; the second, into a flower bud.

Fig. 17. *Menispermum Canadense, L.*, three buds bursting through the petiole scar.

I, II, III, &c., the first, second, third, &c. oldest buds or their equivalents; ps, the petiole scar; lf, the petioles of leaves; S, stems of leaf-branches; F, stems of flowering branches or peduncles of inflorescences. Figures are cited in the text by their numbers.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IV.

MUD-INHABITING CRUSTACEA.

Plate IX.

Among the curiosities of pond life are certain minute crustaceans which spend their entire life in the soft debris and mud forming the superficial deposit at the bottom. The *Canthocamptus* among copepods is commonly found in such situations, but this is less surprising than that members of the cladocera, or shelled entomostraca, with their delicate organization and frail structure should have become adapted to such a life. In many marine crustaceans (copepoda) the accomodation to such a reclusive life is manifested in the retrograde development of many of the organs—eyes, even, being absent in several cases. The present paper is concerned only with a few cladocera, which are peculiar to America or rare both here and elsewhere, and which exhibit curious and instructive modifications as a result of such a habitat. The reader who wishes to familiarize himself with the systematic classification of the group would do well to consult *Die Cladoceren Boehmens*, by Hellich, Birge's *Notes on Cladocera*, and the writer's *Final Report on Crustacea of Minnesota*, while, for a thorough study of the physiology, Weisman's *Beitraege zur Naturgeschichte der Daphnoiden*, is necessary. A special paper on the limicole or mud-loving cladocera was published in the Zeitschrift fuer Wissenchaftliche Zoologie, in 1878, by Dr. Wm. Kurz, and entitled *Ueber limicole cladoceren*. Reference will be frequently made to this paper and this must be understood in all cases of reference to Kurz, unless otherwise specified. These mud-dwellers are happily called "*schmutz-peterchen*" cladocera, *i. e.* "Smut-Johnny," or chimney-sweep water fleas. In America the following species are pre-eminently worthy of the name: *Monospilus tenuirostris*, *Leydigia quadrangularis*, *Alona sanguinea*, *Alona quadrangula*, *Pleuroxus procurvus*, and several other members of the genera Alona and Pleuroxus. The typical cladocera

are graceful in movements and slender in form. Very generally they are more or less boat-shaped and the polished shell is modeled like a clipper, the head-shield forming the prow, while, in a few cases of the best swimmers, (as *Camptocercus*, *Acroperus*, and *Alonopsis*) there is developed a sharp ridge upon the back which bears an unmistakable resemblance to the keel of a boat and, since the animals swim upon the back, may not impossibly serve a similar purpose.

In the mud-loving species, on the contrary, the body is clumsy and approaches the spheroid in form, the antennæ, which normally are oar-like and long, bearing fringed setæ, are short and are armed with claw-like spines and smooth setæ. The post-abdomen or tail, which in the natatory species is reduced in size and subordinated in function, is here enlarged and armed with numerous and considerable spines. The front of the head is either reduced and pointed, or, if there be a long beak, it is turned up out of the way. The meaning of all this is that the animal no longer swims on its back, but creeps humbly and prone and requires the efforts of post-abdomen and antennæ, as pushing poles to make its way through the debris in seach of food. The effect of this manner of life is seen in several other ways, as in the structure of the shell itself. In several of our species the shell, which is renewed periodically, is not, as in other cladocera, moulted, but remains as a sort of outgrown overcoat, after the new shell has become perfected.

The result of this is what might be expected from the sluggish nature of the animal, the supply of clothing thus accumulated becomes so onerous a burden that it no longer could swim if it desired and is thus fettered to the life it early chose. While this is true of a few only, yet in all the limicole cladocera the cuticle becomes indurated and it follows that respiration, which normally takes place from the entire surface of the body, becomes restricted to those membranes in contact with the water within the valves of the shell. As a partial offset to this disadvantage, the strictly respiratory appendages on the feet are enlarged more than in most groups. The sensory organs are modified in several ways. Kurz calls attention to the fact that the antennules are movably joined to the body in the limicole cladocera; they are also, as a rule, rather large and well endowed with sensory apparatus. The compound eye is small and, in one species, as we shall see, fails to develop at all.

MONOSPILUS DISPAR, Sars. is the most remarkable of all filth-dwellers. This animal may probably lay claim to be called the rarest of

the family and has been seen but few times. First described and figured by Fischer, from Russia, it next turns up in Scandinavia, where Sars gives a full Latin description. Norman and Brady find it in England, and Mueller in Denmark, and, finally, Hellich records it in Bohemia. It was also reported from Minnesota, by the writer, in 1884.

Unlike most other limicole cladocera, the body is narrow and high, rather than globose, the head is much depressed and terminates in a slender rounded beak, like the bill of a duck. The fornices or free margins of the head-shield are narrow and flaring. The shell of an old individual is a curious pile of overlapping valves, and is ornamented with concentric series of depressions. The lower margin is nearly straight and bears a row of long curved teeth (not free spines), back of which are two small teeth. The antennæ are short and the antennules rather slender. In this respect our specimen seemed to disagree with the figure given by Hellich. The labrum is of large size and is produced into an acute appendage below, as in most Lynceids. The compound eye is quite absent, but its function is subserved by the larval organ, a quadrate and rather large fleck at the base of the antennules. The intestine is coiled once and one-half times and opens in about the middle of the flat, pentagonal post-abdomen. The latter bears straight terminal claws, each with a single basal spine, a series of rather small triangular teeth, posteriorly, and irregular areas of fine spines upon the sides. The male is not known and many points of interest remain to be made out.

The two species of *Leydigia*, both of which occur in America, are familiar enough and are sufficiently well described to render a repetition of the description needless. It is otherwise with the only species of *Ilyocriptus* yet found in America.

ILYOCRYPTUS SETIFER, Herrick.—The description given in my "Final Report, etc.," is very brief and no comparisons were there instituted with the *I. agilis* of Kurz which is its nearest ally in Europe. The paper by Kurz referred to gives detailed descriptions of the three European species accompanied by elegant plates. We are able, therefore, to draw up the following distinctive diagnosis of the species, hoping thereby and by means of the figures to show the relations of the four species at present known. It is almost certain that we have more than one species in America and the careful description of the known form may make the detection of others easier.

The size varies greatly, a full grown female with eggs in the brood cavity is nearly .90 mm. long and .70 high, while a smaller female measures .65 mm. long by .44 high. The form of the shell is nearest like that of *I. acutifrons*, the heighth being less than in *I. sordidus*, and the angle between the ventral and posterior margins less than in *I. agilis*. The entire length of the post-abdomen in the large female is .56 mm. measured to the base of the caudal stylets, of which length .168 mm. pertains to the claws. The width of the post-abdomen is but .14 mm. Thus it is evident that the proportions of the post-abdomen differ greatly from any of the other species, it being very long and narrow. The terminal claws are exactly as in *I. agilis*, having two small basal spines and a few sharp serrations near the apex, anteriorly. Near the base of the claw is a cluster of small spines of two sizes, then begins a series of about sixteen lateral teeth averaging .02 mm. in length and extending to the sides of the anus. Above this point the contour of the margin is convex and is ornamented with nine spines twice as long as the preceeding. Then follow the prominences which bear the long and simple caudal setæ. Besides the above mentioned spines there are four spines on either side upon the lower posterior angle of the post-abdomen which are four times as long as those of the previously mentioned continuous series (*i. e.* .08 mm.) Above, the abdomen is hirsute or thorny as in *I. agilis*, and the process for closing the brood sac is similar. It will be seen that the post-abdomen differs in armature as much as in form from other species. From *I. sordidus* it differs in the following points :—the claws are not pectinate behind but are serrate in front, the anal opening is higher and the details of the spines vary ; from *I. acutifrons* it differs in that the claws are not pectinate, neither is there a spine in front of the claws, and the anus is not terminal; from *I. agilis* it differs, in that the shape is different, there are fewer enlarged spines, and the shape of the nine spines above the anus is different. The head is convex, resembling *I. sordidus* most nearly, but the antennules are much longer and more slender than in any other known species. They are .17 long and about .016 mm. wide, while the longest seta is .084 long. The antennæ are almost exactly as in *I. sordidus*. The labrum has the usual shape, as have the jaws and other appendages. The margins of the shell are ornamented with spines simply pectinate or barbed, as in *I. agilis*. In *I. sordidus* these spines are variously branched and in that form alone of the European species, according to Kurz, is there a failure to per-

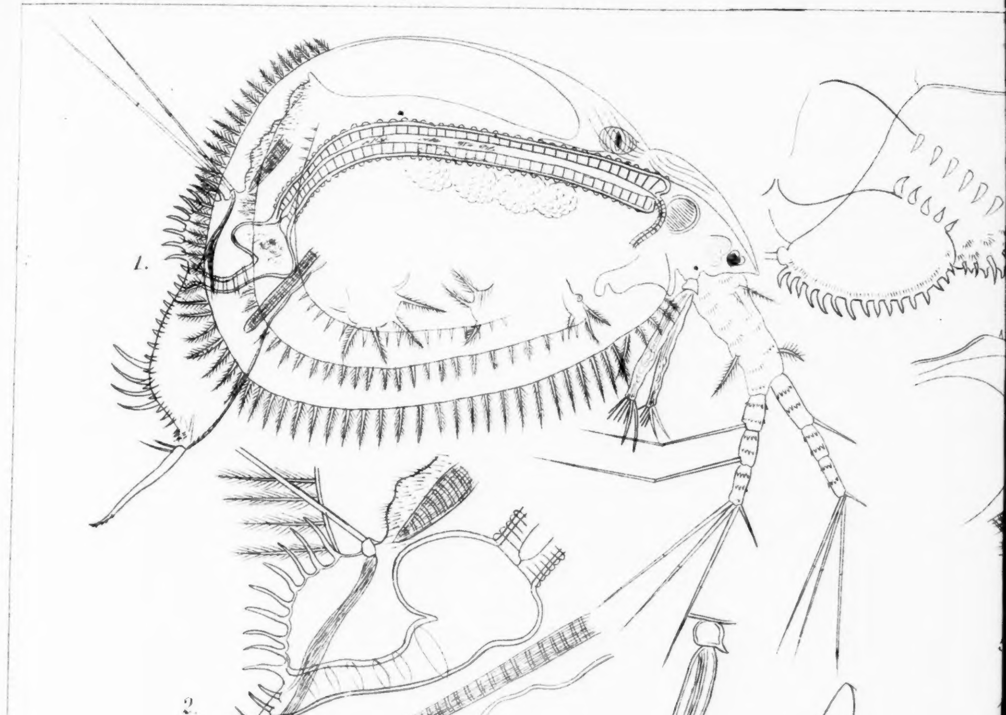
fect the moult; in our species, which has simply pectinate setæ, the old coverings are all but uniformly retained. The spines of the lower posterior margin are from .16 mm. to .20 mm. long.

Such are some of the chief peculiarities of the species, but, to make the relation between the four species of this little-known genus even clearer, if possible, the following comparative table is appended.

The shell moulted periodically —	*I. agilis.* *I. acutifrons.*
The shell not moulted but retained—	*I. sordidus.* *I. spinifer.*
Antenules not more than eight times as long as broad—	*I. sordidus.* *I. agilis.* *I. acutifrons.*
Antenules more than eight times as long as broad—	*I. spinifer.*
Claw of post.abdomen pectinate—	*I. sordidus.* *I. acutifrons.*
Claw of post-abdomen not pectinate—	*I. agilis.* *I. spinifer.*
A strong spine in front of claw—	*I. acutifrons.*
Fine bristles or none in front of claw	*I. sordidus.* *I. agilis.* *I. spinifer.*
Anus opening near the claws—	*I. acutifrons.*
Anus about midway of the posterior border—	*I. sordidus.* *I. agilis.* *I. spinifer.*
Marginal spines of shell much branched—	*I. sordidus.*
Marginal spines nowhere much branched—	*I. agilis.* *I. acutifrons.* *I. spinifer.*
Elongated anal spines on either side, four or five, very long—	*I. spinifer.*
Elongated anal spines more numerous—	*I. agilis.* *I. acutifrons.* *I. sordidus.*
Upper (one to three) spines of the supra-anal series modified and enlarged—	*I. acutifrons.* *I. agilis.*
Upper spines like the others—	*I. sordidus.* *I. spinifer.*

Plate IX.

Fig. 1. *Ilyocryptus spinifer*, Her., female.
Fig. 2. Post-abdomen of same.
Fig. 3. Antenule of same.
Fig. 4*A*. Jaw of *I. sordidus*.
Fig. 4. Post-abdomen of same.
Fig. 5. Post-abdomen of *I. agilis*.
Fig. 6. Head of same, antennæ being removed.
Fig. 7. Antenule of *I. sordidus*.
Fig. 8. Spines on edge of shell of same.
Fig. 9. Post-abdomen of *I. acutifrons*.
Fig. 10. *Monospilus dispar*, female.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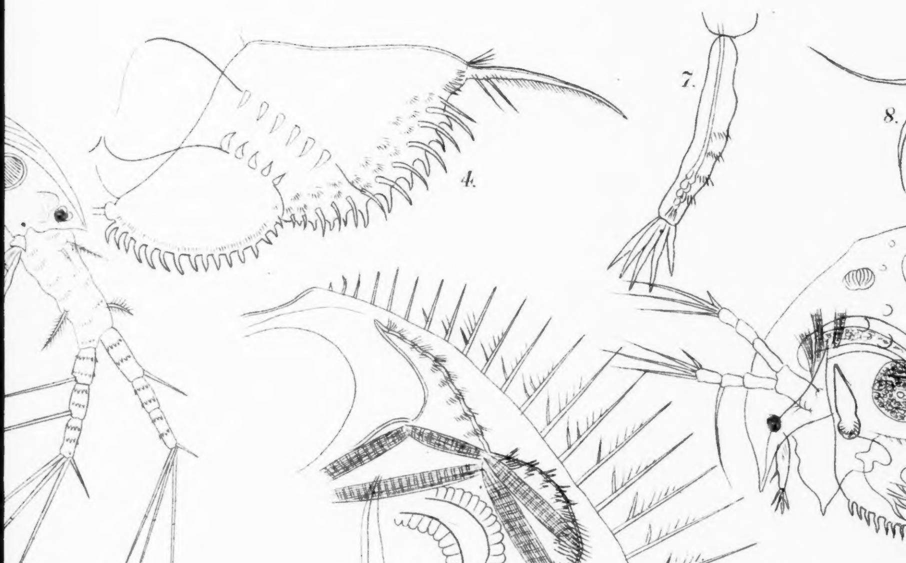
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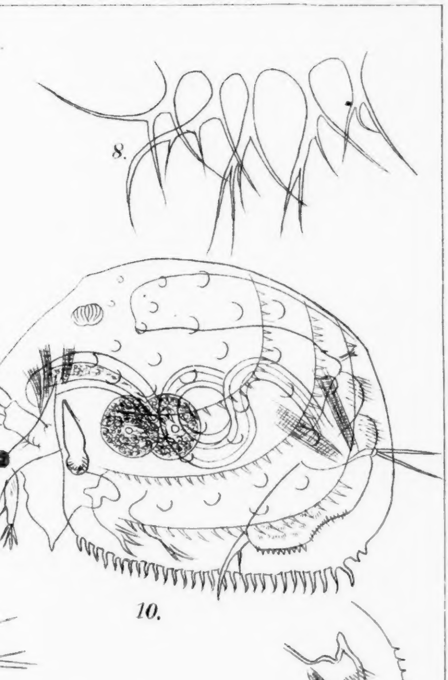
Plate IX.



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V.

NOTES ON AMERICAN ROTIFERS.

BY C. L. HERRICK.

[*Plates II—IV, and Plate X.*]

Introduction.—In the series of papers here begun, it is expected to treat the subject in somewhat the following order: First, in an introductory section, an outline of the general characteristics will be given, then we shall proceed to a description of species without attempting to treat them in systematic order, finally, if permitted, space may be devoted to a review of the classification and a more detailed discussion of anatomy and development. The present installment attempts simply to describe a few of the common species of a number of genera.

A rotifer may be described as a worm-like, bilateral, metazoan, moving by means of a circum-oral trochal disc, and either adherent or free-swimming. Many of the animals of this group are exceedingly small and are greatly exceeded in size by certain Infusoria, and it was this circumstance, as well as a certain outward similarity in appearance, which led Ehrenberg to include both under the one head and to ascribe to Infusoria the same complicated structure he was able to make out in rotifers. Living in all fresh waters, these animals are among the most accessible objects for the microscope, yet, on account of the care necessary in their study and the scattered literature, they have been much neglected in America.

The body of all rotifers exhibits a tendency to segmentation, which is, however, mainly confined to the integument. The inner organs are but slightly affected by the jointing, except the muscular system which is, moreover, largely responsible for the number and arrangement of the segments. Very generally the body terminates posteri-

orly in a several-jointed abdomen or "foot," which bears two caudal stylets and contains glands which secrete a gummy fluid used by the animal in temporarily adhering to other objects. The form varies from nearly spherical or round lense-shaped to terete and extended. The cuticle is modifided in various ways, sometimes appearing like a bivalve shell and thus hightening the resemblance to certain entomostraca and explaining why older naturalists classed the rotifers under crustacea. The cuticle may be smooth or beautifully ornamented and produced into long spines or marked off into areas outlined by impressed or raised lines. The cuticle is secreted by a hypodermic layer which is often seen obviously to consist of cellular tissue. Notwithstanding the protection afforded by a chitinous shell, some species (as *Melicerta ringens*) build for themselves a tube composed of materials gathered from the water and apparently connected by a cement secreted in a gland near the mouth. Such an envelope may be compared to those swallows' nests eaten in Asia, or the case of a caddis-fly. Some of the species live in colonies, and when the colony is spherical, as in *Conochilus*, it is a veritable microcosm—a sphere of active, voracious creatures whirling through aqueous space. In only one case is it certainly known that a moult takes place, and facts seem to be unharmonizable with the theory that such a change of coats is affected.

The cilia of the trochal disc or "wheel" are arranged in the greatest variety of ways in different genera. The attempt is made to refer all these forms back to a fundamental form—*i. e.* a double circlet of cilia, the outer of which is largest and serves as locomotory, while the inner set is under the control of voluntary nerves and serves simply to bring food within the pharynx. In many cases there is really no indication of such a distribution and the cilia seem to be merely isolated clusters of hairs scattered about the oral end of the body. Several of the rotifers are parasitic and cling to the less exposed parts of the body of certain Amphipods, or on Annelides, or are endoparasitic. The muscles are often very conspicuous and, when large, show the striated structure well. The alimentary canal, maxtax, and the contractile water vessel have muscular tissue af another sort.

The nervous system is most difficult to study and little is certainly known of its structure. Usually there can be made out a considerable granular mass over the maxtax and in close proximity to the eyes, this is assumed to be the principal ganglion. From the chief or central ganglion fine nerves pass to the muscle and organs of sense.

The eyes are double or single and are sometimes supplied with a lense; they are always furnished with a dark red pigment and, very generally, rest directly upon the ganglion. There are occelli at various points in the trochal disc of some species. The sense of touch is delicate, and there is often a special tactile tentacle, or palpus with minute tactile rods. This may be reduced to a slight papilla or a pit, with sensory hairs. No other sensory organs have been discovered, although Huxley fancies that to be an octocyst, which the Germans call the "Kalk-beutel," *i. e.* the lime-sac. This is a spheroidal sac, containing irregular grains of lime. The function is unknown, but it may be simply a reserve supply to be used in preserving the rigidity of the indurated parts of the body.

The mouth is more or less ventral, while the anus is dorsal. The mouth leads by the pharynx into a roomy and expansible crop or directly into the maxtax or masticatory organ, and this is armed with chitinous appendages of the most various form, but referable to a simple type. Here there is a central anvil-like part called the *incus* and two lateral *mallei* which consist of a handle (or *manubrium*) and a head (*uncus*) which beats upon the incus and reduces the hard parts of the food. The maxtax opens into a narrow ciliated œsophagus which, in turn, leads to the stomach proper.

The stomach is sometimes quite distinct from the succeeding parts of the system, but sometimes can only be distinguished by the large size and absorbtive character of its cells. Into the stomach is poured the secretion of a pair of glands which may be compared to the so-called salivary glands of insects or the liver and salivary glands of vertebrates. The size of the glands is dependent on the diet of the animal. In carnivorous species the glands are small, while in others they become quite conspicuous. The intestine is clothed with long cilia and opens into the cloaca or common receptacle of the reproductive, water vascular, and alimentary systems. In some species, however, the stomach is a cœcum and has no anus. Males uniformly lack the alimentary system and are short-lived creatures of love. In some cases evident messentaries support the digestive tract.

The excretory system consists of a pulsating bladder, opening into the cloaca, and two lateral vessels of various form, upon which are flagellate chambers which contribute to keep up a circulation between the cavity of the body and this vascular system.

Respiratory and circulatory organs, in the received sense, are absent,

respiration taking place, as in many small entomostraca, through the body surface, and circulation is affected by the rythmical movements of the digestive tube and the ciliary action in the later vessels.

In mature females much of the body cavity is filled by the ovary and the yolk masses or eggs. The ovary is disc-shaped, botryoidal or variously contoured and in the grey substance exhibits hyaline spots containing the nucleated ovule cells. A part of the ovary temporarily secretes the yolk when the egg reaches maturity, so that the appearance of the viscera differs greatly at different times. The egg, after extrusion, is commonly carried about in a delicate external brood-sac as in copepoda.

To add here the details of the development of the egg would lead us too far. The male, as before said, has no functional digestive tract and is not only much smaller than the female, but suffers a reduction in many organs. The sensory organs are, however, well developed. The testis is spindle-shaped or oval and opens in a papilla, which also contains the opening of the water chamber or pulsating vessel. The spermatozoa are rod-like or thread-like and motile.

The Rotifera are found in fresh and salt water over the entire globe. Some species may be found in damp situations on land. They exceed even the lower crustacea in their great adaptability to changes in outward surroundings. Not only is drought not destructive to the eggs, but the animal itself endures a long period of dissication. Other notes upon the habits must find their place under the special descriptions.

Descriptive Part.—As above stated, the following descriptions are given without attempt at orderly arrangement, with the expectation of ultimately attempting a systematic review. In cases where lack of literary aids make positive identification impossible, the description alone will be given, awaiting future identification.

GENUS FLOSCULARIA, *Oken.*

The head is margined by five oval processes bearing exceedingly long setæ of excessive fineness. The mouth is central, with a funnel-form opening. There is a crop-like vestibule, separated by a partition from the pharynx, except in the centre, which is perforate, the opening being margined by several pendulous cilia. The adult is attached by a long, jointed foot, but the young is motile and possesses eyes, which are aborted after the metamorphosis.

FLOSCULARIA ORNATA, *Ehr.*

is not a rare inhabitant of the pools of Minnesota. The very full descriptions of this species, given by various authors, would seem to have exhausted the subject, but we do not even yet feel sure that the so-called species are not local or age variations. The other species are *F. appendiculata*, *F. proboscidea*, *F. complanata*, *F. longiloba*, and *F. trifolium.*

Of *Rotifer* and *Callidina* we find a number of species, but reserve the consideration of the group for another occasion.

Notommata furnishes several species which are very abundant and striking, but a large number of works are necessary for their study.

GENUS EUCHLANIS, EHR.

The lorica is oval and composed of an arched dorsal shield and a plane ventral one. The lorica in front is broad and presents a large opening for the head. The shell often has a carina above, while the dorsal shield is movable upon the ventral. The trochal disc is strongly ciliate and bears two terminal sensory organs with clumps of tactile hairs. There is a single cervical eye and the viscera are highly differentiated. The foot has four short segments and two terminal lanceolate claws.

EUCHLANIS (DILATATA) HIPPOSIDEROS, *Gosse.*

[*Plate III, Fig.* 2.]

The identification of our species with the above is made in spite of minor points of disagreement which may be looked upon as the result of faults in the descriptions or slight variations in structure. Eckstein gives the length at .45 mm., while Eyferth says .23 mm. Our species varies only between .22 and .24 mm. and is quite uniform, so far as observed. The form is oval, the lorica being excavated before and behind, as shown in the figure, although it is not often seen as clearly as drawn.

The trochal disc has two broken circlets of cilia, and on either side the head is a pit densely ciliated within. The drawing given by Eckstein shows the arrangement well. Two curious sensory organs occupy the very front of the head. The ganglion is very large and quadrate, the eye being near its anterior part and quite large. The maxtax is quadrate, showing the component parts well. The stomach is ob-pyriform and there are two accessory glands. The ovary has very large nuclei and the egg is of great size. The contractile vessel

is clearly seen and all the details of the water vascular system may be made out with ease. The lateral vessels are tortuous canals, while upon them are seated beaker cells, the flask-shaped base of which connects directly, by means of a curved tube of less diameter, with the main canal. The mouth of the flask is directed downwards and has a small opening near which is the point of insertion of a long cilium which extends upward into the flask, where it is constantly in motion. There seems to be no reason to doubt that by means of these beaker-cells the vascular system is in communication with the perivisceral cavity. The foot is comparatively slender and has, aside from distinctly cross-striate muscles, two large foot glands which open in the ends of the rather long dagger-shaped claws. A pair of fine bristles springs from the dorsal surface of the last segment of the foot.

The following measurements were taken:

No. 1.	lorica	.22 mm. long.	No. 2. .22	No. 3.	.24
	"	.14 mm. wide.	.14		.15
	foot	.06 mm. long.	.06		—
	claws	.07 mm. long.	.07		.072
	jaw capsule	.06 mm. long.	.06		.048

Found in Minnesota during the whole summer among water plants.

EUCHLANIS AMPULIFORMIS, *sp. n.*

[*Plate II, Fig.* 3.]

This species, which deviates toward *Salpina*, is smaller than the above and, in outline, is somewhat flask-shaped. The back is carinate and the flat ventral plate is excavated posteriorly with a cordate opening. The head is produced and densely hairy below. The maxtax is small, but the cervical eye is very large. The nuclei of the ovary are very conspicuous, although the egg is not as large in proportion as in the above. The foot is four-jointed and the claws are elongated and somewhat curved. The lorica is .16 mm. long, the claws .08 mm. Another individual measured .20 mm. and the claws were .12 mm. long. This species was seen but twice, June 18th, 1884, in Minnesota.

POLYARTHRAEA.

The family includes the two genera, *Triarthra* and *Polyarthra*. In both genera the foot is wanting and appendages of the sides of the body take its place. The body is not segmented except anteriorly and the form is not definite. The genus first mentioned has two lateral and a ventral appendage, while in Polyarthra the appendages are collected in groups upon the opposite sides. In both genera the egg is carried about as in *Anureæ*.

GENUS POLYARTHRA, EHR.

A single species has so far been encountered and I am able, with the works at hand, to discover no reason to doubt its identity with *P. platyptera* of Ehrenberg.

When swimming freely this animal seems to consist of two quadrilateral segments, the first, or head segment being considerable shorter than wide in outline, while the body is a third longer than wide. The trochal ciliation is slight. Two sensory organs are conspicuous upon the front of the head and the eye occupies the middle of the first segment near its posterior margin. The maxtax is very large and the stomach is short, with a tubular intestine. There are two prominences on either side of the body near the front, each bearing three lanceolate spines. The egg is very large and is perhaps half as bulky as the whole body. The contractile vessel is small and little could be seen of the lateral vessels. The length is .10 mm.; width, .08 mm.; setæ, .088 mm. long. This species seems rare and was found among plauts in standing water during June and July of 1884 and 1885 near Minneapolis.

The group of genera termed *Macrodactylea* or *Longiseta* includes such animals as have a more or less elongate and frequently cylindrical body, often strongly curved, and possess the following characters. The cuticle is considerably indurated; the terminal segment of the foot is long; there is usually a lack of symmetry exhibited by the claws or maxtax; and the cilia are sparse upon the trochal disc.

The following genera are at present included in the family:

Scaridium, Monura, Furcularia, Distemma, Monocerca, Mastigocerca, Diurella, Heterognathus, Rattulus.

GENUS DIURELLA, BORY DE ST. V.

The body is more or less perfectly cylindrical, and curved either ventrally or dorsally. The claws are rather long and frequently seem united, and are curved ventrally, The eye is cervical and single. There is a sensory tube upon the upper (dorsal) part of the disc. Three species are described, although doubt exists as to the specific value of one of these; they are *D. tigris*, Ehr., *D. Rattulus*, Eyferth, and *D. stylata*, Eyferth, to which a species is added below under the name *D. insignis*. The common species in America is

DIURELLA TIGRIS, (*Ehr.*) Bory.

The descriptions and figures of European authors vary remarkably in this instance, but from them all we are able to gather sufficient to

make it reasonably sure that our species is really *D. tigris*. It is quite variable in size and form. The cylindrical body is strongly curved ventrally. The head is distinctly set off from the body by a suture as represented by Eyferth but not by Eckstein. The sides of the neck extend into a sharp spine on either side, which, however, may be easily overlooked. There is a sensory cylinder which forms a third prominence upon the front. The foot consists of but a single evident segment which is quite short. The appendages assume a variety of appearances. Usually they seem to form a flattened triangular plate curved in the same plane as the body. This appearance is figured by Eckstein, though he describes the appendages as consisting of two pairs, the outer half as long as the inner, both being united at the tips into one plate. Eyferth says, on the other hand, that the foot bears two unequal, bristle-like, curved claws, but his drawing shows two *equal* claws. Our experience confirms Eyferth's account. Like *Rattulus*, this species moves in circles or arcs of circles when lashing its tail, but has the power of moving in a straight line by the use of the cilia alone. The maxtax is nearly as drawn by Eckstein. The chief organs are two anchor-like indurated processes which are unlike in length and form. The walls of the maxtax are furnished with ring-muscles. The stomach is glandular and its cells contain large globules of fatty matter. The intestine is pear-shaped and furnished with numerous cilia. The contracting vessel is large but the lateral vessels are not easily seen and I can add no details. The single cervical eye is large and seated on a large elongate ganglion. The ovary is small and the egg, when present, occupies the left side of the body on its ventral aspect. The total length is about .20 mm. of which the body forms .16 mm. The longer claw measures, in large specimens, .048 mm. and the shorter only .036 mm. Sometimes I fancied that I saw two lateral spines as described by Eckstein. The width of the lorica is about .65 mm. This species was encountered in Ohio and Minnesota in all situations and seasons.

DIURELLA INSIGNIS, *sp. n.*

(*Plate IV. Fig.* 6.)

A larger species than the above is found in Minnesota. The length, exclusive of the claws, is from .17 to .20 mm. The claws are .06 mm. long, one being much longer than the other. There are spines in the cervical region similar to those described in in the above.

The body is much more slender, while the viscera do not differ essentially from *D. tigris*.

GENUS MONOCERCA, Ehr.

This genus includes elongated, nearly cylindrical or conical forms, having a single greatly elongated claw and more or fewer accessory spines on the last segment of the foot. The maxtax is elongate, with unequal indurated ridges. The stomach is oval and the intestine cylindrical.

The only specimens of this genus as yet seen resemble very closely *M. rattus* of Ehrenberg but are somewhat longer. The lorica is .30 mm. long while the claw is .22 mm. The foot consists of two segments, both of which are very short, while the last carries four or more unequal spines. The pulsating vessel is elongate oval but the details were not studied. This rotifer it quite rare.

GENUS DINOCHARIS, Ehr.

The lorica is cylindrical or prismatic, with a wide opening in front. The head is distinct and feebly ciliated. The eye is cervical. The foot is long, rigid, and three jointed. The claws are long and the foot bears, beside these, long spines anteriorly and behind. The whole shell is densely covered with granulations or spinules.

Dinocharis Pocillum, *Ehr.* (?)

(Plate II. Fig. 1.)

The most abundant form of this genus in America varies so greatly in both size and details of structure that one is tempted to identify it with the most frequent species of Europe in spite of variations from the descriptions of authors. The outline of the lorica is cup-shape and its symmetry is broken by two ridges near the posterior edge, passing transversely. It is 1 1-5 times as long as wide. The first segment of the foot is short and bears two long curved spines above. The middle joint is twice as long and nearly cylindrical. The third segment is about as long as the first and bears two curved claws four times as long as the segment and also a short spine about as long as the segment.

The whole body is about .24 mm long, including the claws, which measure .08 mm. The eye is large and is seated on an ovoid ganglion. The ovary is large and the nuclei are quite distinct. The egg is obliquely placed and nearly as long as the width of the lorica. Two curved elliptical glands lie in front of the stomach. The lateral vessels of the vascular system are large. Encountered only in Minnesota.

A somewhat larger form, also found in Minnesota, has more slender claws and seems to lack the spine on the last joint of the foot. The shape is otherwise the same.

The cast-off shell of still a different form, in which there is an indication of segmentation near the anterior of the lorica, was once seen.

GENUS SALPINA, Ehr.

Somewhat resembling *Euchlanis*, but having spines upon the front and posterior margins of the laterally compressed lorica. There is a median area above, which is less perfectly indurated than the sides, giving rise to two ridges. The foot is short, three-jointed, and bears two lanceolate claws. The eye is single and the ciliation of the trochal disc rather strong. The maxtax is large and the digestive tract well differentiated. Water-vascular system with two or three beaker-cells on either side. The egg is carried about with the parent after extrusion.

Salpina affinis, *sp. n.*

(*Plate II., Fig. 4.*)

This species is so allied to *S. mucronata*, Ehr. that it is with some hesitation that a new name is proposed. While agreeing in most characters, it differs from that species in having the upper pair of anterior spines much longer than the lower and curved downward and in having the lower pair of posterior spines much longer than the single upper one and curved upward. *S. mucronata* is said to measure but .15 to .16 mm., while our form is .22 to .24 mm. long and .10 mm. wide. The anterior spines measure .045, length of claws, .06 mm. The whole shell is granulated and there is a band in front, set off by a distinct line. There is a sensory tube which bears a bundle of cilia at its end, and which usually projects from between the two dorsal spines of the lorica. The eye is lunate and seated on a very large, almost spherical ganglion. The maxtax is very large and opens into a slender œsophagus. The stomach is glandular and saccate. The very large egg is ventral. No careful study was made of the viscera. Minneapolis, May.

The species of the genus, aside from those mentioned, are *S. spinigera*, Ehr., *S. brevispina*, Ehr., *S. ventralis*, Ehr., *S. bicarinata*, Ehr, *S. redunca*, Ehr., *S. dentatus*, Duj., and *S. polyodonta*, Schm. There is reason to suppose that several of these are but varietal forms.

GENUS MONOSTYLA, Ehr.

Shell depressed, oval ; head opening large, notched before and behind. The foot has two short basal segments and a long terminal one ending in a small spine, hence appearing as though bearing one long spine. The eye is single and situated at the base of a large ganglion. The maxtax is large and quadrate. The viscera are simple.

Monostyla (quadridentata, *Ehr.* ?)

Two species of Monostyla have been thus far encountered, one of which may be identical with *M. quadridentata* of Ehrenberg. The body is bell-shaped or inverted pear-shaped, the oral margin being produced into two sickle-shaped spines turned outward, which are distinct from the acute margins of the shell itself. The body is composed of two segments or apparent segments, the second being small and conical. The terminal joint of the foot is slender and elongate, bearing a thorn-like spine. The ganglion is very large. The maxtax is also large and opens into a sack-like alimentary canal not evidently subdivided. The shell in this species is ornamented with granules. Length of lorica, .15 mm., width, .11 mm., terminal caudal joint, with spine, .08 mm. Found in June, in Minnesota.

A second species is smaller, measuring from .11 to .12 mm., foot .04 to .08 mm., width, .11 mm. The shell is smooth and the curved spines are absent.

The following species are known :—

Monostyla lunaris, Ehr., *M. cornuta*, Ehr., *M. closterocerca*, Schm., *M. oophthalma*, Schm., and *M. macrognatha*, Schm.

GENUS DISTYLA, Eckstein.

Shell ovate conical, closed behind, except for the small opening admitting the foot. In front, the opening is wide and guarded on either side by projecting angles. The foot is one-jointed and bears two equal, divaricated spines. The shell may be smooth or ornamented with raised lines and serrations. The eye is single and seated upon a considerable ganglion. Two species are described by Eckstein from Europe (*D. gissensis* and *D. ludwigii*) and two additional ones occur in America.

Distyla minnesotensis, *sp. n.*

This is a large species, .25 mm. long, with a pear-shaped body of two segments, the first being .20 mm. long and of equal width. The second segment is .05 mm. long and has an oval slit behind for the insertion of the foot and permitting its free lateral motion. The claws

are .13 long and slender, the terminal third being attenuated. The ganglion is small and bears a single red eye. The trochal disc is retracted by four powerful muscular bands. The stomach is globular and glandular. The short segment of the foot is moved by pairs of evident muscles. This species was but once seen in July.

DISTYLA OHIOENSIS, *sp. n.*

The lorica is .12 mm. long and its form is much as in the previous species. Width of lorica .084 mm., length of claws .028 mm. The sides of the lorica project in front to form a tooth on either side of the head. The lorica is sculptured into regular areas upon the first segment. There is a quadrate plate projecting over the base of the claws. The latter are attenuated toward the end. The details of structure are not known.

GENUS SQUAMELLA, EHR.

The three genera *Squamella*, *Metopidia*, and *Lepadella* agree closely together, being characterized by the presence of four, two, or no eyes respectively. The organization is much as in Euchlanis. The lorica consists of an oval, arching, scale-like shield above, and a flattened plate below. The foot consists of three short joints terminating in two acute claws The head terminates above in an oval scale-like appendage.

They only species belonging to this group as yet seen was hastily identified with *Squamella bractea* and, in absence of further information, we will simply give measurements in addition to the figure, in which, by the way, but one pair of eyes is represented, leaving us to infer that the animal is *Metopidia* rather than *Squamella*.

Length .08 mm.—.14 mm. Width (in the latter case) .12 mm. Found several times in Minnesota.

GENUS STEPHANOPS, EHR.

The lorica is depressed, and frequently extends into spines posteriorly Head covered with a shield, which, when viewed from before or behind, is in shape like a halo There are two eyes, occupying the extreme sides of the head. The foot is three jointed and ends in two lanceolate claws, between which springs an awl-shaped spine.

STEPHANOPS MUTICUS, *Ehr.*

(*Plate X, Fig. 9.*)

A specimen of this species was taken in July, 1885. The lorica is oblong oval, seeming two-jointed behind. There is a slight crest

above. Both segments extend dorsally into prominences which only appear when the animal is viewed from the side. The head is covered by a thin semi-circular shield, which is slightly arched. The cilia of the disc are feeble, but the sensory tube is distinctly seen. The first joint of the foot is quadrate, the two following being of equal length but different diameter. The claws are ovate lanceolate and short. The accessory spine is awl-shaped and shorter than the claws. The length is about .10 mm Eckstein gives very good and accurate figures of this species, his description of the viscera is also valuable.

The following species of this genus are known: *S. lamelleris*, Ehr. with three spines behind. *S. cirratus*, Ehr. with two spines behind. *S. longispinatus*, Tat. *S. ovalis*, Schm. *S. tridentatus*, Fr.

GENUS BRACHIONUS, Ehr.

A large genus containing curiously armed and ornamented species. The body is depressed, oval or quadrate in outline, presenting a very large anterior opening always guarded by spines or teeth. Behind, the shell may be rounded or armed with spines like those in front. There is only a small opening upon the ventral aspect through which extends the foot. The ventral surface of the body is generally plane while the back is arched and may be set off into areas by elevated lines. The maxtax is prismatic and complicated. The egg is carried about attached to the body of the parent, as in *Anuræa*. The males are said not to be rare in this genus.

Brachionus bakeri, *Ehr.*

A single gathering taken in Granville, O., in September, contained a species belonging in the section of this genus characterized by the multiarticulate foot.

Our species is sub-quadrate in outline and more or less expanded back of the middle. The whole length, including spines, is from .30 to .40 mm. for adult females. The oral margin, above, is produced into six spines. The median pair are longest and curve decidedly outward and may be from .05 to .08 mm. long; between them is an incision, through which ordinarily projects the sensory tube. The outer pair of spines are half as long and also curve outward. Midway between these pairs is a short spine or tooth. The ventral edge is notched in the middle, but not toothed. The width of the body is from .18 to .22 mm. The posterior portion of the shell extends into two pairs of spines, of which the outermost are very long (.10–.14 mm.) and project directly backward or slightly outward or are uniformly curved. The inner pair of spines immediately border the

opening for the exit of the foot and are curved plates. The foot, which can be almost wholly withdrawn within the lorica, is composed of a closely ringed basal portion terminated by a short rigid joint, bearing two conical claws and blunt processes. The claws are perforated by the ducts of large cement glands. The flexibility and extensibility of the foot are truly wonderful. The whole shell is covered above with fine granules, but is not otherwise marked. The eye is large and is seated on the ventral side of a large ganglion. The maxtax is very wide and short. The manubrium is a curved plate and the uncus consists of several fused plates (see drawing). I have seen the animal attempt to masticate a large diatom and, after failing to crush it, reject it by reversing the usual movement of the jaws. The pharynx is ciliated and funnel-form. The œsophagus is not ciliated, but has ringed muscles which, when in motion, give the appearance of a valvular arrangement. The stomach and intestine are strongly curved upon each other, the former being glandular with fatty spheres in its walls, while the latter is furnished with a dense coating of cilia. The pulsating vessel is not large, but the lateral vessels with their beaker cells are quite conspicuous. This species, which agrees with *Br. Bakeri* closely, is common in Ohio, (September).

Another species, known only from a single gathering and imperfectly studied, differs from all known species in having a single pair of spines before and behind and a foot which at the base is multiarticulate, but ends in the two long segments, the last with two quite long claws. The shell is nearly smooth. This species may be called *Br. intermedius*, as it partakes of the characters of both sections.

Brachionus militaris, *Ehr.*

(*Plate X, Fig. 10.*)

It is interesting to compare with the above a related species which is quite common in the west and which belongs to that section of the genus characterized by the absence of the ringed basal arrangement of the foot. This form, which may not be properly Brachionus, resembles decidedly the above in the form of the body. The anterior margin extends into ten teeth, of which the superior median are longest and curve ventrally. All the other anterior teeth are doubly curved, the points extending outward. The posterior part of the body bears two pairs of spines, the relative position (and size) of which is not constant. The outer pair are always longer and project outward and

backward. The foot consists of three slender joints, the last of which bears two lanceolate appendages somewhat longer than the segment preceeding. The whole shell is covered with minute points. The trochal disc is broken up into five lobes and the cilia are of two sizes. The measurements of one specimen are given as illustrating the proportions. Length .20 mm. exclusive of foot, width .14 mm., terminal stylets .024, lateral, posterior spines .028 mm., anterior spines about .04 mm.. From the side, the ventral surface (in outline) is seen to be plane while the dorsal is composed of two inclined planes (or is "humped.") The foot is moved by two pairs of muscles. The contracting vessel is unusually large. The maxtax and the position of the viscera seem to be as in other species of Brachionus. The animal seems most to resemble *B. militaris*, Ehr. of the European species.

PLŒSOMA LENTICULARE, *gen. et sp. n.*

(See figures facing Index.)

The animal for which the above generie name is proposed, was several times seen in a gathering taken at the reservoir near Hebron, Ohio, in November. The general form is very similar to that of many minute bivalved crustacea (*Chydorus*), with which it was associated. The lorica is composed of two ovate valves, which are partially united below, so that the foot springs from the middle of the ventral margin. The animal is laterally compressed. On the dorsal aspect of the lorica are several distinct ridges arranged about as follows: A pair of short transverse markings occupy a point posterior to the middle of the dorsal aspect; anterior to these, and beginning at either end, spring diverging lines which lead to notches of the anterior margin; behind, two ridges lie on either side the median line and extend to the acute posterior end of the shell. Several lines border the above described markings on either side and are approximately parallel to the axis of the body. Seen from the side, the lorica is elliptical and is truncate in front and acute behind. The dorsal line is a uniform curve, while the ventral is prominent near the middle at a point some distance in front of the point of union of the valves. Seen from above, the front half is quadrate, while the posterior half is triangular. The lorica is lenticular, considered as a whole, and is marked by minute hexagonal or irregular depressions.

The head is armed with two long sensory organs and has two sorts of cilia. The outer series is quite feeble, but the ventral prominence

bears several elongated setæ. The maxtax is oval and seems to be but slightly armed. It is furnished, however, with distinct annular bands of muscles. The eye is cervical, and is seated on the under side of a considerable ganglion. The foot is multiarticulate at the base, as in *Brachionus*. Two distinct joints follow this portion, the last being longer and bearing two oval, appressed spines. Of the internal organs little was seen. The stomach is glandular and the egg of but moderate size. The vascular system was not seen.

Length, .24 mm., height, .15 mm., width, ,10 mm. Frontal processes, .03 mm., spines of foot, .025 mm., last joint, .02 mm.

GENUS ANURÆA, Ehr.

Closely related to *Noteus* and *Brachionus* is a genus of curious rotifers in which the foot is entirely absent ,so far, at least, as can be seen. As in Brachionus, the anterior opening is protected by spines or teeth, while there may or may not be simtlar teeth behind. The lorica is usually distinctly separable into a dorsal and ventral shield, and the dorsal scutum is marked off into geometrical figures by raised lines. There is a single cervical eye The egg very generally remains attached to the body and may be mistaken for a part of it.

Anuræa sp.

A species differing from all European forms is very common in the West. The form is hexagonal in outline, the length being 1.4 times the width (exclusive of spines). The anterior margin of the hexagon is wider than the posterior. The dorsal scutum is produced into six long spiny teeth, of which the middle pair are much the longest and are strongly curved outwards and downwards. The remaining pairs are sub-equal and project outwards like the horns of an altar. The ventral part of the anterior margin is excavated in the middle and bears a series of small sharp teeth. The whole shell is ornamented with circular prominences, and, in addition to this, above there are strongly raised lines blocking off the shell into thirteen regular areas and leaving two other areas about the front. The character of these ridges is best seen from a side view. The eye is cervical and the trochal cilia are strong for the genus. There is also a sensory tube.

The following measurements, owing to an accident, may not be accurate, but will give the proportions: Length, .1 mm., width, .054 mm., longest spine, .024 mm.

GENUS PTERODINA, Ehr.

The lorica is flattened, round, or ovate in outline and flexible. Head funnel-shaped, entirely withdrawn into the body when at rest, furnished with two lines of cilia. Stomach sac-like with large cilia. The foot is ventral and consists of a ringed basal portion and a short terminal joint which bears no claws. The intestine is said to be continued through the tail having the anal opening at its end.

The Pterodina is a good subject for use in obtaining a knowledge of the rotifers as the viscera are quite distinct, the cross striation of the muscles and the ciliated or beaker-cells of the lateral vessels being particularly distinct.

Pterodina patina, *Ehr.*

(*Plate* 1, *Fig. III.*)

The form is circular with a slight emargination in front for the withdrawal of the head. The head is funnel-shaped and bears a double disc having good sized cilia. When extended the eyes are seen to occupy a position about one-third the width of the disc from its sides. The pharynx is closely ciliated and leads into a comparatively large maxtax in which a partial fusion of parts has taken place. The stomach follows upon a very narrow oesophagus and is a curved sac composed of large cells, each of which is filled with granular contents and has fatty spheres within it. On either side the stomach is a strong muscle passing from the sides of the head to the posterior third of the body where it is fastened. When the head is withdrawn the muscles are curved, but upon the protusion of the head become straight. On either side the stomach is a large glandular mass composed of numerous lobes made up of fused cells with large translucent flecks which may be globules of the secretion. These glands open back of the maxtax. While the stomach is curved to one side, the intestine lies behind the tail and is curved upon itself, opening, as claimed by Eckstein, into a canal excavated in the tail. It is indeed certain that the tail contains a canal and is ciliated at the distal extremity but we have never been able to verify the statement referred to. The tail seems to be more slender in our specimens than figured by European writers, though it is exceedingly contractile. The contractile vessel seems to be absent but two very distinct lateral canals are to be seen. The breaker vessels are long and the cilia active. The ovary occupies one slde of the body, while the egg nearly fills the other when mature. Large nuclei are discernible imbeded in a granular mass of yolk. The

margin of the shell seems to be granulated and extends beyond the body-cavity. The tail often is directed at right angles to the body and is then overlooked. The lorica is about .20 mm. in longest diameter. The tail measures over .07 mm. The trochal disc, when expanded, is .05 mm. wide. A small specimen, but fully adult was but .17 mm. long. Mr. Stokes mentions a species of this genus but does not identify it. There are two other species, viz. *P. elliptica* and *P. clypeata*, Ehr., which latter occurs as a parasite on species of *Assellus*. I have a confused recollection of having seen such a rotifer parasitic upon *Gammarus*. *Pterodina complanata* of Gosse is almost certainly identical with *Pt. patina*.

FAMILY ASPLANCHNÆA.

This family includes abberant rotifers, which lack the posterior opening of the digestive organs and are considerably reduced in other respects. The foot is sometimes almost entirely absent, its position being marked in these cases by the glands simply. The body is sac-like and often consists of a single segment in which the various internal organs are very readily seen. The head is broad and sparsely ciliated. The maxtax is enlarged and to it is appended an extensible crop, while the incus is not highly indurated and the mallei are modified to form a prehensile pair of nippers or pliers. The stomach may be very extensible and a part is very highly glandular. The water-vascular system is highly developed and there is generally an accessory canal bearing the minute beaker cells, while the lateral vessels themselves are tortuous and elaborate. Most of the species are carnivorous, while others live upon algæ and like plants.

GENUS ASPLANCHNÆA, Gosse.

The genus is characterized by the sac-like body and the large size and well differentiated organism as compared with *Ascomorpha*. The details mentioned under the family apply.

Asplanchna magnificus *sp. n.*

(*Plate II, Fig.* 2.)

This, the largest species of the genus, is most like *A. Myrmeleo*, but is considerably larger and appears to differ from it in several other particulars. The general form is a prolate spheroid truncated anteriorly and slightly flattened ventrally. The oral end is furnished with six

discrete clumps of cilia and two sensory processes. The crop is large and distensible, the forceps are smooth and toothless The œsophagus is long and muscular. The stomach is composed of very large cells and is held in place by bands of connective tissue. There are accessory glands between the stomach and crop. The ovary is pear-shaped (not horse-shoe-shaped, as in *A. Myrmeleo*), and can be seen to be made up of an elongated ribband of cells folded upon itself. The pulsating vessel is exceeding large and powerful, while the lateral vessels are convoluted canals ; accessory to the latter, there are nearly straight tubes bearing about twenty beaker-cells. The foot is two-jointed and contains small glands. The muscular spstem is highly developed and consists of strong bands passing backward from the head and frequently branching before they are inserted upon the very pliable external wall. Two pedate cells lie upon the viscera and may represent the visceral nervous system. The nervous system was otherwise found to consist of ganglia upon the oral aspect, one of which bears a single red eye, and which send nerve-fibers to all parts of the body. The animal feeds upon species of minute crustacea, especially of the genus Chydorus. The greatest length is .9 mm , width, .66 mm.. foot, .15 mm. This species was figured in the writer's Final Report on the Crustacea of Minnesota, where also may be found the figure of

ASPLANCHNA *sp?*

This species, which seems to resemble *A. Brightwelii* of Gosse, is purse-shaped, being constricted about the head. The jaws are bidentate at the end and ribbed. The foot is entirely absent, but its position is indicated by the orifice of small glands. The stomach of the only individual of this species seen contained a number of the lorica of what may be *Anuræa longispina*, Kellicott.

EXPLANATION OF PLATES.

Plate II.

Fig. 1. *Dinacharis pocillum*, Ehr.?
Fig. 2. *Asplanchna magnificus*, sp. *n.*
Fig. 3. *Euchlanis ampuliformis*, sp. n.
Fig. 4. *Salpina affinis*, sp. n.

Plate III.

Fig. 1. *Pterodina patina*, Ehr.

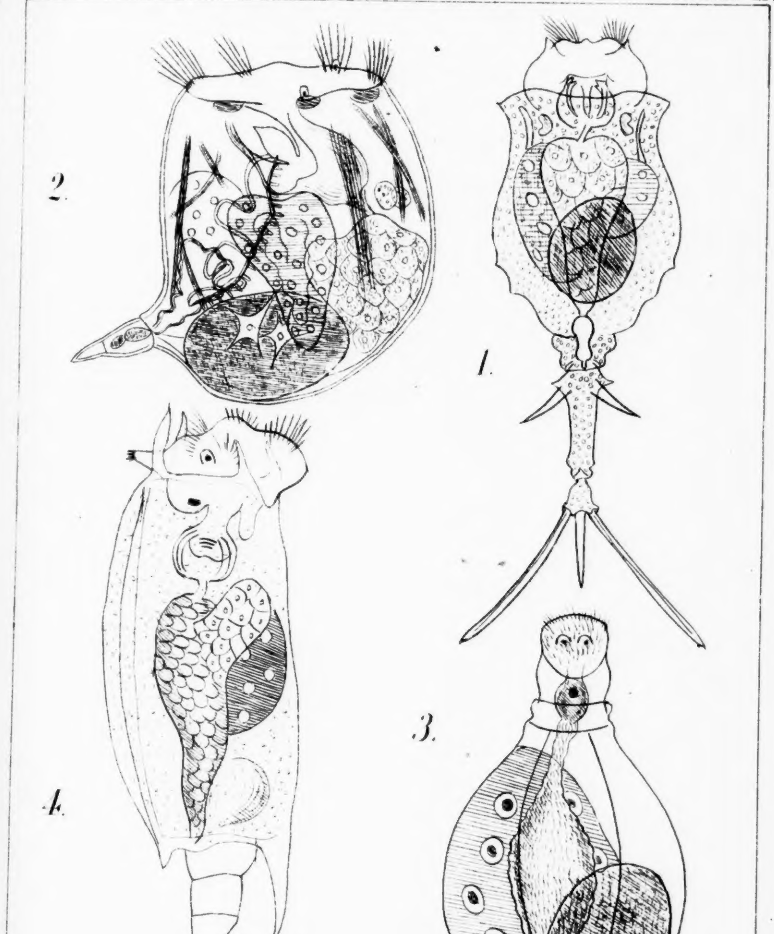
Fig. 2. *Euchlanis hipposideros*, Gosse.
Fig. 2.[1] do portion of lateral vessel with beaker cell.
Fig. 3. Undetermined.
Fig. 4. *Amphileptus gigas*, C. & L.

Plate IV.

Fig. 1. Undetermined.
Fig. 2. *Squamella bractea*, Ehr.
Fig. 3. *Monostyla quadridentata*, Ehr, (?). The foot is somewhat too long in the drawing.
Fig. 4. *Polyarthra platyptera*, Ehr.
Fig. 5. Undetermined.
Fig. 6. *Diurella insignis*, sp. n.

Plate X.

Fig. 5. *Spirostomum teres.*
Fig. 6. *Ophridium paradoxum.*
Fig. 7. *Anuræa* sp.
Fig. 8. *Distyla Minnesotensis*, sp. n.
Fig. 9. *Stephanops muticus*, Ehr.
Fig. 10 *Brachionus miliatris*, Ehr.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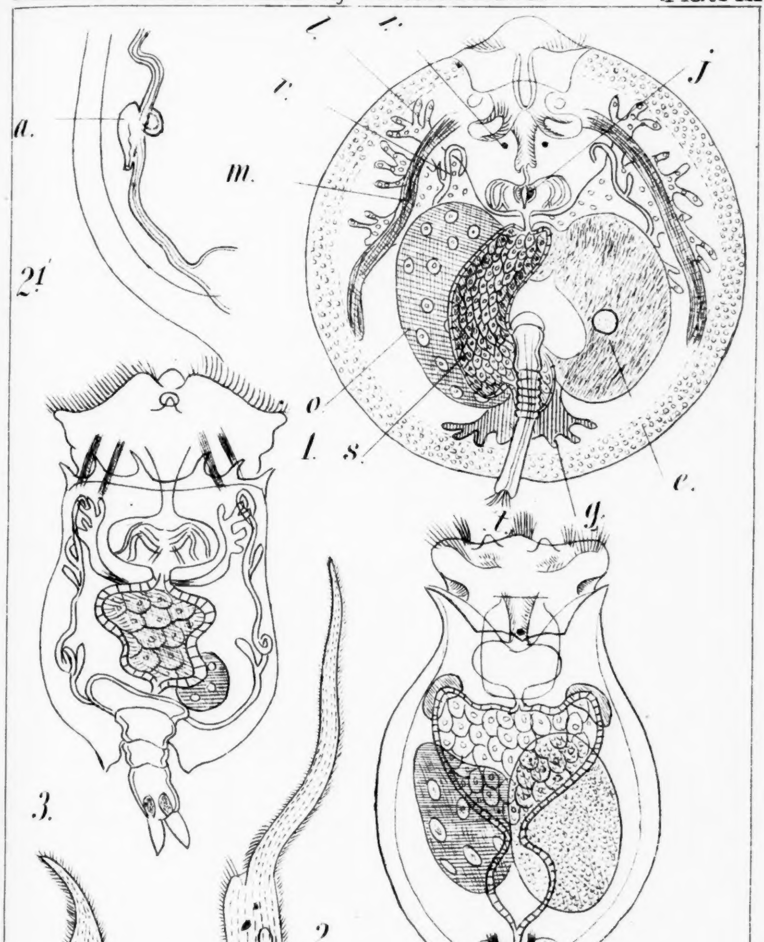
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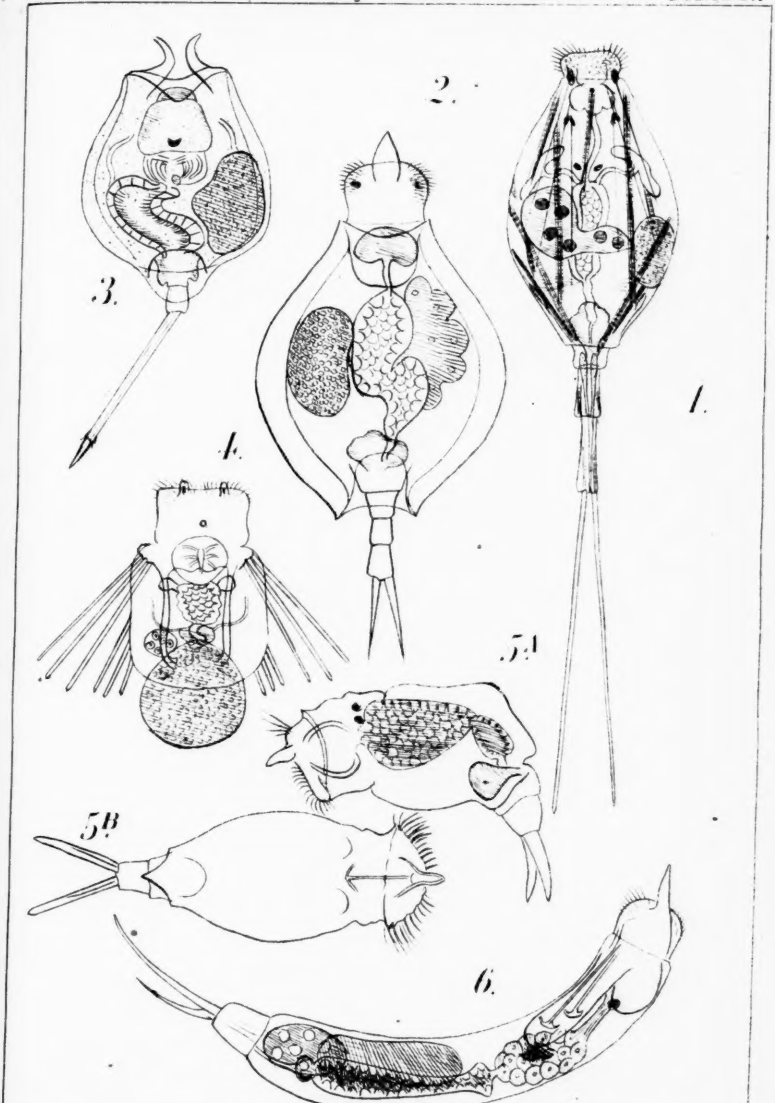
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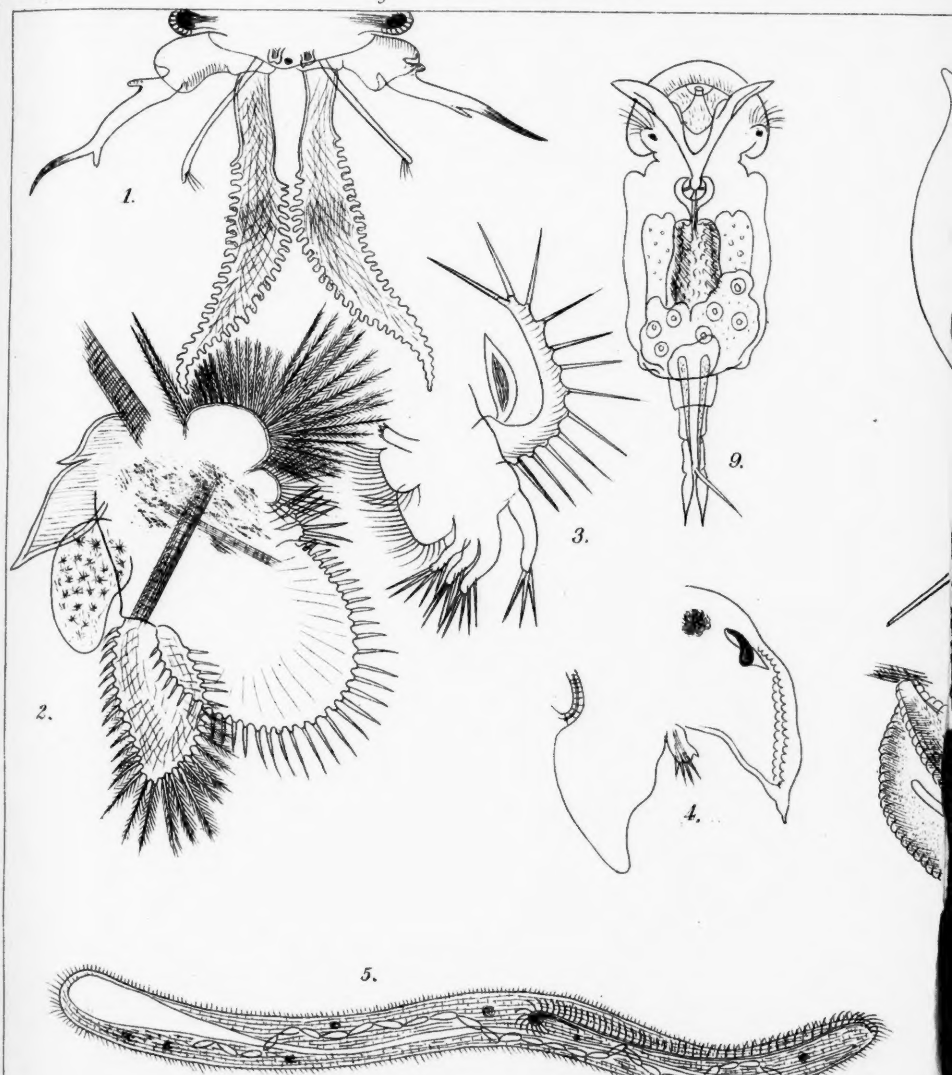
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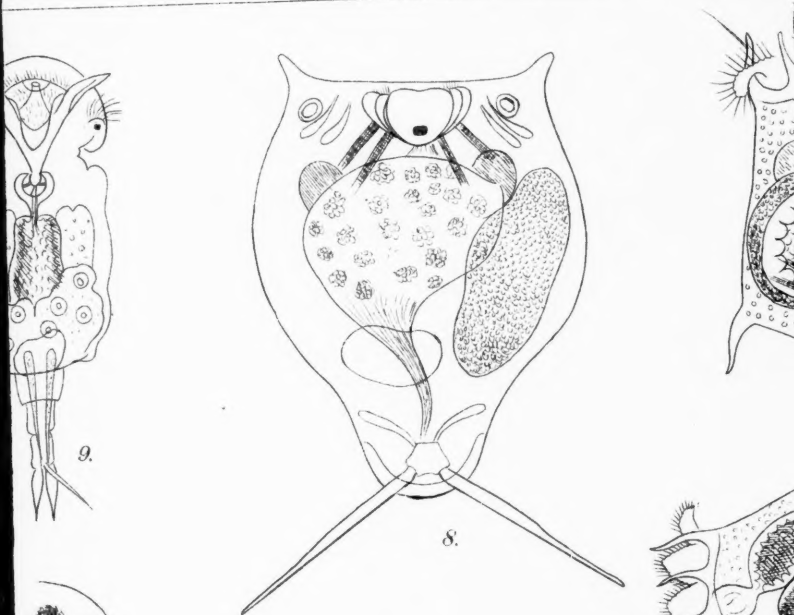
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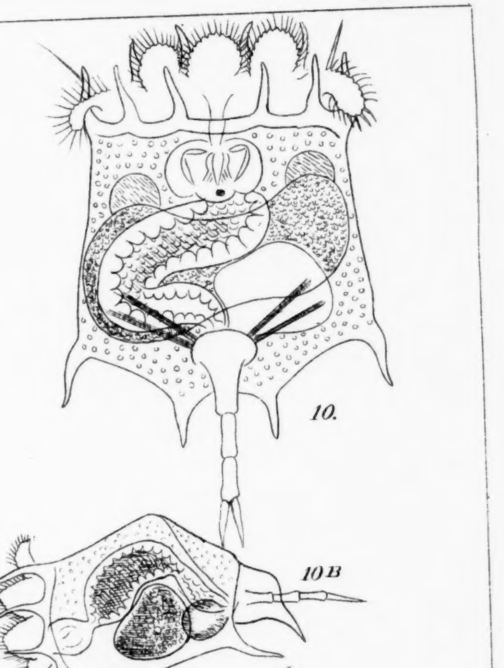
Plate X.



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VI.

THE CLINTON GROUP OF OHIO.

BY A. F. FOERSTE.

Prospectus.

The title, as given above, does not correctly indicate the scope of the papers here presented, but will very well serve to designate the field which I have laid out before me, and which I expect to cover by means of a series of articles, of which the present paper is the first. Descriptions of all the important exposures in the state, sections of the strata, analyses of rock, and paleontological features will be furnished wherever practical. A collection of fossils, which already bids fair to rival those at Waldron, Indiana, is expected to furnish the basis of a description of the fossils of the group as presented in this State. It is also intended to identify in an independent manner the true relations of the geological strata usually included by the name Clinton Group, in our State and Indiana. Although it may be well to state at the outset that present indications seem to favor a closer relationship to Niagara strata, and especially those of the west, than is generally conceded ; nevertheless this conclusion has not been hastily drawn, and is not irrevocably held. I shall only attempt to present the facts and state their probable bearing, and then allow the reader to draw his own conclusions. In order to determine more definitely the stratigraphical relations of the group with corresponding formations of the west, especially those of Indiana, a series of sections taken at different stations, from both Ohio and Indiana, will be undertaken at an early date. Although the project in some respects may seem rather extensive, the large amount of material already collected gives promise of its ultimate accomplishment.

GEOLOGY.

In southwestern Ohio, immediately above the Cincinnati Group, lie a series of strata, formerly known, both scientifically and popularly, as the Cliff Limestone. They are so designated, for instance, in the second annual report of the Ohio Geological Survey, undertaken in 1838, by W. W. Mather. Many of the cliffs and cascades in this part of the State owe their origin to the peculiar characteristics of this formation. Later, however, a division into two groups was made, and after a more extended study by Prof. Edward Orton the upper section was identified with the Niagara Group, but the lower was called the Clinton. In the reports for 1869 and 1870, these distinctions were carefully made. At various times, however, authors have seen fit to express doubt of the correctness of the name employed for these strata, and Prof. James Hall, especially, has had occasion to do so in the 12th annual report of the Indiana Survey. For our purpose it will be well enough to retain the name, Clinton Group, at least for the present, but it is expected that after a presentation of all the facts, others, perhaps, will be ready to adopt some other term.

The Clinton is not a group of any great depth. For its western exposures in Ohio, ten to fifteen feet would be a fair estimate. In its eastern exposures in Highland and Adams counties "its *average thickness* is somewhat increased, but probably never exceeds 40 feet, and this thickness is sometimes attained in the northern district as a *maximum*, as for instance, at Yellow Springs, in Greene county." (Italics my own). A section of the geological series of Highland County gives a thickness of 50 feet to the Clinton Limestone. (Geo. Surv. Ohio, 1870, page 298 and section at page 310.)

The Clinton Limestone rarely affords any extended surface exposures, but is found like a narrow line separating the Cincinnati and Niagara Groups of the State, and usually is seen in close connection with both. A section of rock belonging to the Clinton age, therefore, generally also includes both the upper and lower strata.

The rocks of the Cincinnati Group, in Ohio, are quite level, showing no marked local variations in their dip. At their junction with the Clinton Group, however, they frequently become unfossiliferous, and the rock is replaced by less solid shales and bluish clays. The surface of the group also becomes very undulating in character, frequently attaining a dip of four feet in forty. As a consequence the superposed rocks of the Clinton Group are also very undulating.

They maintain, however, an average thickness, indicating that, whatever were the causes which had disturbed the bed of the Lower Silurian sea, these had disappeared by the time the strata of the Clinton Group were deposited.

In other words, at the close of the Lower Silurian age, the ocean became shallow; large valleys and gullies were washed out from the beds of the Cincinnati Group. The silt was deposited as a blue clay, which terminates the strata referred to this age. On this uneven and very undulating bed, the rocks of the Clinton Group were deposited. At this time a portion of the Lower Silurian rocks must have been exposed, as the researches of the last geological survey revealed evident shore markings in several places, containing the pebble-washed fragments of the Lower Silurian strata.

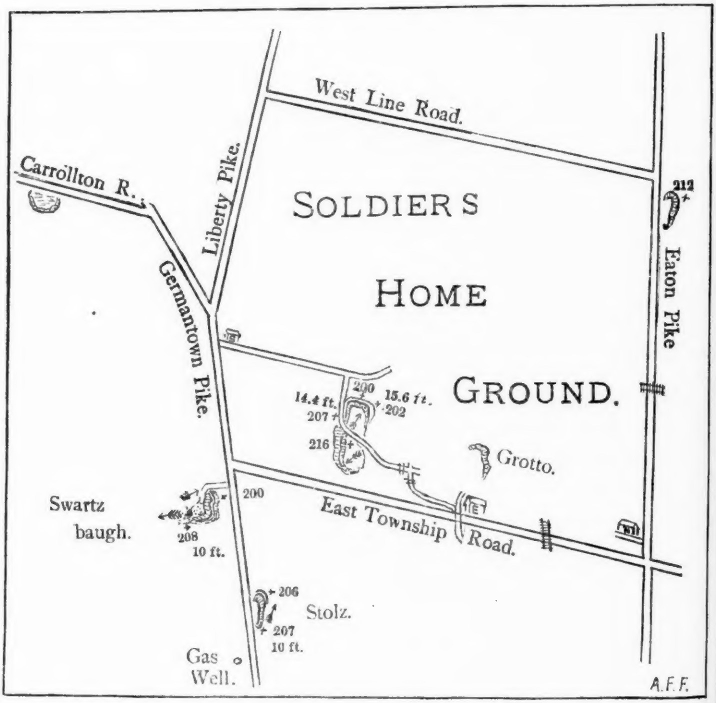
In fact, the very fragmentary condition of most of the fossils found in this group indicates the action of shore waves upon the accumulated deposits of this sea. The slight variation in the thickness of the group may readily be explained by the conditions brought about by its uneven bed. The washings of an otherwise shallow sea would naturally be very unequally deposited near the shore line. At a distance from the land the fine silt would be almost equally deposited, but near the shore the washings would accumulate most in the depressions of the ocean bed. And, although the inequality of deposition would of course not be very great over any large extent of territory, nevertheless it is sufficient to account for the variation observed. At Soldiers' Home, where there is a dip of seven feet in one hundred, the rock increases one foot in thickness. This is the most marked instance which has fallen under my observation.

The Clinton Group consists of a crystalline, crinoidal limestone of variable color, sustaining a high polish, extremely fossiliferous in places, differing in this particular from the Niagara strata immediately overlying it.

Between it and the Niagara Group is a fine clayey or marly bed, about nine inches thick, which in some places becomes quite hard, and in others is replaced by a soft blue clay. In connection with the Dayton limestone it usually attains the hardness of stone and is characterized by a number of minute species, which, considering the small attention hitherto paid to this course of stone, is unusually great. For the present it will be called the Beavertown marl, on account of

its prominent development near that village, and will be considered as a part of the Clinton Group.

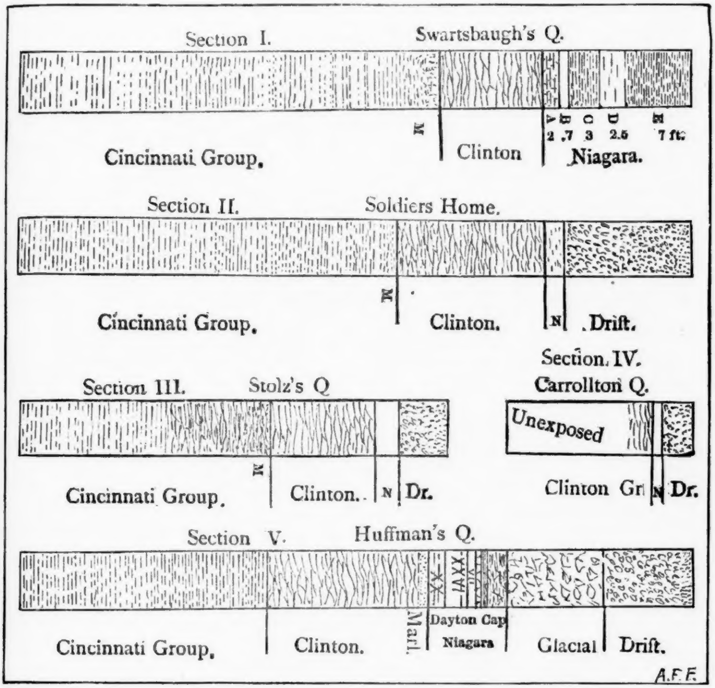
The first, and by far the most important series of exposures to be mentioned, are those included in the Soldiers' Home district.



SOLDIERS' HOME QUARRIES.

The Soldiers' Home grounds, embracing about a square mile of land, are situated two and a half miles west of Dayton, on a series of hills overlooking the city. At their foot, exposures of the Lower Silurian strata are frequent, but at their top, rocks of the Upper Silurian age take their rise, and have a steady dip towards the west, bringing up, one after the other, the formations of a higher age.

About half a mile from the Home, at the side of the Germantown Pike, a well, driven for water, gave rise to a flow of gas, lasting some months. Owing to neglect or other causes, the supply has now ceased, evertheless, the existence of inflammable gas in the Lower Silurian rocks is of some interest.



Stolz's Quarry, (Section III.)

A short distance westward, the pike runs upon a bed of rock belonging to the Clinton Group. North of the road a quarry has been opened, which displays both the Niagara and Cincinnati Groups, nevertheless a satisfactory section of the Clinton Group has as yet not been attainable.

All measurements of the elevation of rocks in the various sections are reckoned from the sidewalk at the Court House in Dayton. These measurements are due to the kindness of Mr. A. Kiehl, who aided me materially in this part of the work. The top of the Cincinnati Group is at 193.51 at the first station. In a section made near by the Cincinnati layer was not exposed but the lowest point in the Clinton was at 196.74; the top of the Clinton, 206.31; the top of the Niagara exposed, 208.68. The thickness of the Niagara was therefore 2 ft. 4.5 in.; and that of the Clinton, considering that the dip from the first named station, east of the section, was slight, but westward, a thickness of twelve feet would be more than conjectural. The rock is crystalline, consists of uneven "lenticular" layers, unequally fossiliferous, the fossils being found in "pockets" or special accumulations, irregularly disposed throughout the group. Numerous fine heads of *Dalmanites Werthneri* are quite abundant here, and for many things it ranks with the Soldiers' Home quarry itself in productiveness.

The Clinton ends in a top of blue clay containing large crinoid beads, free specimens of *Chaetetes*, *Rhinopora*, &c. It is about five or six inches thick. Only the blue clay referred to the Cincinnati Group is exposed. The Niagara Group consists of a yellow limestone, unfossiliferous as far as known, lying in uneven broken courses from two to five inches thick. It has no commercial value, but the Clinton stone is much used for academizing roads and streets, and is profitable on a small scale, as a gain of $492 with an expenditure of $426 in one instance will show. During this year, 1885, up to August an expenditure of $356 realized a gain of $547, which is quite profitable considering the small amount of time put upon the quarry. The inferior quality of the Niagara limestone at this quarry is to be especially mentioned as it is the exact equivalent of the Dayton limestone and the succeeding quarries farther west gradually assume the characteristics of the Dayton stone, thus forming a complete and instructive series for comparison.

Swartzbaugh's Quarry. (*Section I.*)

On the same pike within a few hundred feet from the south-east corner of the Home grounds is a second quarry. It is placed behind a farm-house, dipping northward into the hill near the barn. The top of the Cincinnati Group is here represented by a bed of blue clay. In the sections made, however, this bed was not reached. The bot-

tom of the Clinton Group as far as worked was at 198.21 ft.; the top, at 208.04 ft.; but a conjectural thickness of twelve feet would not be far from correct. The stone presents the usual characteristics, but seems to be less fossiliferous than some of the neighboring quarries. It is peculiar in showing fissures, extending east and west, distant from each other about 9 feet, found at no other station in the Clinton Group. In the southern part of the quarry there is a sudden dip to the south and the stone is broken, as though the blue clay layer beneath had given way and permitted the stone to sink. The fissures in the rock are perhaps also explained in this manner.

The Niagara exposure is a little more than 15 feet in height. The base of the series is composed of broken, irregular, yellow layers of stone from two to five inches thick, making a total of 1.9 feet. Above is a 9 inch course of blue flagging stone, which was at one time quarried and sold in slabs for pavements. It resembles a fair quality of Dayton limestone of which it is the stratigraphical equivalent. Formerly when the Clinton stone was not exposed and the Cincinnati Group was in plain sight along the hill below, and the great dip of the rock had not yet been determined, the identity of this stone remained for a long time a puzzle. Above the blue flagging is a series of shales 3 ft. thick, varying in character, sometimes represented by broken courses of yellow limestone 2.5 ft. thick, composed of a nine inch layer above and below, with the intermediate layers more or less shaly in character. Sometimes the remainder also becomes somewhat shaly. Last in the series is a 7 ft. layer of yellow Niagara stone, formed of very broken, thin courses, from half an inch to two inches in thickness, frequently becoming shaly. The top of the blue flag layer in the southern part of the quarry is at 210.70; seventy-five feet north, at 204.10; fifty feet west, at 203.89. This would give a dip of 4 ft. 5 in. in fifty feet towards the north, and only 2.5 in. in the same distance, towards the west; the last dip is reliable, owing to the very even stratification of the blue flagging. At the same point the bottom of the heavy Niagara stone is reached at 206.92; the top at 209.49. Farther west the top is again reached at 207.87, and the summit of the thin shaly courses at 214.85. All the Niagara stone here exposed is unfossiliferous as far as known. In some parts of the quarry the Niagara stone is all tumbled together, destroying its original stratification. I presume that the action of ice during the glacial epoch could readily account for this, since all the quarries round about, where the

stone is hard enough, show evidence of this glacial action in the form of grooves, scratches and the planed surfaces of the stone.

Carrollton Pike Quarry. (Section IV.)

Along the Carrollton pike about half a mile from the Home Grounds, on the east side of the road, a quarry was opened, which developed a layer of Niagara flagging stone 5 or 6 inches thick. It was smoothed above by glacial action, was found within two feet of the surface, and hence was readily worked, and sold to advantage as a fair quality of Dayton limestone. In several places in Dayton it was used without extra preparation for side walk purposes. Beneath is a layer of thinner stone and then limestone of the Clinton Group, of little or no commercial value, and therefore, not quarried. Here specimens of *Orthis fausta* were found. This species has also been found at Swartzbaugh's quarry, in the same position, namely at the very summit of the Clinton Group.

Eaton Pike Quarry.

North-west of the Soldiers' Home grounds, on the north side of the Eaton pike the Clinton rock is quarried. Neither the top nor the bottom of the series is exposed but the two levels taken register 211.92 ft. and 205.50, which give a thickness of 6 ft. 5 in., but the real height of the strata is no doubt much greater. Numerous bryozoans are found here.

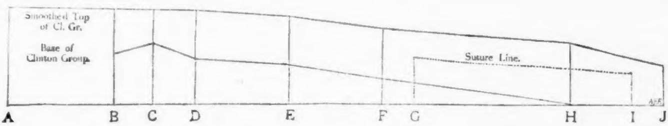
The Grotto.

East of the Soldiers' Home along the railroad, a cut through rock of the Cincinnati Group displays the characteristic fossils of this group. South of the terminus of the railroad in the grounds are the socalled grottoes. These were formerly the site of an old quarry, and belong to rocks of the Clinton Group. Owing to the underlying bed of blue clay the Clinton Group is usually a great water bearer. At Soldiers' Home one of the grotto springs is fed in this way, and two springs of the same nature in the quarry south of the grotto give forth a steady flow of water all year. The grotto is now used for floral effects only.

Soldiers' Home Quarries. (Section II.)

The Soldiers' Home quarry is the finest exposure of the Clinton Group in the State. Being constantly in operation, it has proved the most productive place for fossil remains. Both the Niagara and Cin-

cinnati groups are shown in the same section, and the thickness of the Clinton Group as here obtained is strictly accurate.



Stations.	Top of Clinton Group.				Base of Clinton Group.				Stations.	Seam in Clinton.			
	Distances.	*Height above Court House Corner.*	*Dip in feet.*	*Dip for 100 feet.*	*Distances.*	*Height above Court House Corner.*	*Dip in feet.*	*Dip for 100 feet.*		*Distances*	*Height above Court House Corner.*	*Dip in feet.*	*Dip for 100 feet.*
A	150	208.95	1.00	.67					G	175	198.08	3.29	1.88
B					30	198.94	*2.08	*6.93	I		194.79		
C					35	201.02	3.44	9.83					
D	75	207.95	1.38	1.84	75	197.58	1.17	1.56					
E	75	206.57	2.46	3.28	75	196.41	2.70	3.60					
F	150	204.11	3.19	2.16	150	193.71	5.54	3.69					
H	75	200.92	4.54	6.05		188.17							
J		196.38											

*Dip towards the west.

A section of the eastern half of the quarry, beginning at A near Massachusetts Avenue, and extending to the eastern limit, is represented by the table and section just given. The distances are reckoned to the next succeeding station on the line; the height is calculated from the level of the side walk at the Dayton Court House; the first list of dips consists merely of differences of elevation between consecutive stations; in the second these are reduced to the standard of 100 feet. The dip unless marked by an * is toward the east.

The difference in direction between the base and the top of the Clinton Group is quite evident, and is owing to the effects of glacial action which has planed off the stone without regard to its dip, or elevation, as shown for instance at station C. This is still more evident if the dip near the western end of the section be considered, where the base of the Clinton is 4 ft. below the same 40 feet north. The entire eastern half of the quarry shows glacial scratching, planing, and grooving.

It is frequently supposed that the Clinton contains no regular seams, separating the strata. Whereas this is true in a general sense, as compared for instance with Cincinnati or Niagara formations, nevertheless quite regular seams are occasionally found also in the Clinton group, especially in the section now under consideration. A long seam, followed with comparative ease for 175 ft. showed a dip of 3.29 ft. in this distance. A comparison of this line with the base of the group shows that the strata thicken in the depressions of the underlying bed. This is also shown in the western half of the quarry, where the group is 14.4 ft. thick at the spring, and 15.6 ft. at a point 150 ft. north-west of the same, showing an increase of 1 ft. 2.5 in. The elevations at the spring are: top of Cincinnati group 192.63; of Clinton group, 207.01. Along the western end of the quarry the elevations of the Clinton: are 202.73 at the S. W. corner, 200.07 at the middle, 202.15 at the N. W. corner, 202.36 at a point east of the latter. Here the top of the Niagara reached 204.26 showing a thickness of 1.9 ft.; it is a yellow, somewhat shaly stone, becoming frequently quite hard. Taking the Niagara stone as shown at the Soldiers' Home, Carrollton pike, and other quarries farther west, a good idea of the variability of the base of this group can be formed. In the western part of the quarry the base of the Clinton Group consists of a greyish or almost white stone, composed of finely comminuted organic remains, of which the structure has become more or less obscure. Here many bryozoans have been found in a fine condition. *Clathrapora Clintonensis* and *Retepora angulata* in fronds 2 feet and 1 foot in diameter respectively have been seen here. Other fossils, however, are rather scanty in this stone. Most of the group, however, is composed of a bluish solid limestone, becoming pinkish or red by oxidation, and abounding in fossil forms. The summit of the group in the north-western part of the quarry is especially prolific in various species of *Orthis*. The summit of the Cincinnati Group is composed of blue, clayey shales, several feet thick, and very undulating. The notable fact is that these undulations are mostly local, the strata taken as a whole, maintaining a comparatively even inclination, as will be seen by a reference to the map.

In the rocks of the Clinton Group, at Soldiers' Home, so many species are found, and so much work has been done, that it would be difficult to mention the prominent features. Bryozoans, found here in numbers, are said to be still more common at the Eaton pike quarry.

Platyostoma Niagarense is not unfrequent. Glabellæ and pygidia of two species of *Illænus*, are abundant, as are also various shells, corals, &c. The fossils are not equally distributed. Thin courses of rock are not apt to be very productive. In the thicker interspersed layers, however, which show external signs of fossils, considerable numbers are frequently developed by breaking the stone. Throughout the Clinton Group the fracture is irregular, and it is very difficult to obtain entire specimens. It is rarer still to obtain specimens completely loosened from the rock, as one or the other face is apt to be inseparably connected with it.

DAYTON LIMESTONE QUARRIES.

South of Dayton a continuous series of quarries extends from Beavertown to a point about a mile and a half northeast of the Insane Asylum. Some of these have been abandoned, but in those now in operation the Dayton and overlying strata of the Niagara are shown in section, and small exposures of the Clinton are not infrequent. As a means of comparison with the district just described, a section of one of these quarries is given.

Huffman's Quarry, (*Section V.*)

About three quarters of a mile towards the southeast of the Asylum for the Insane, is a quarry, belonging to Mr. W. P. Huffman, of Dayton. A single section of the Clinton Group is said to have been obtained here, while constructing a drain. The strata were 13 feet thick; the color is light pink, and its fossils are rather few. The Niagara Group consists of the Dayton limestone, and a few layers of "blue cap." The Dayton limestone consists of a 20 in. course of stone, surmounted by a 26 in. and a 7 in. course. The 20 in. course separates into a 12 in. layer, succeeded by two 4 in. layers. The 26 in. course, even more readily, is divided into a 20 in. and a 6 in. layer. The 20 in. layer is naturally the most profitable, and is quarried in large slabs. The blue cap begins with a 10 in. course of poor quality, followed by an 8 in. course, still more inferior and often broken. Above this, 18 in. or more of thin slabs, usually in small pieces, may be found. The color of this blue cap is denoted by its name; its commercial value is destroyed by its poor weathering qualities and the irregular and broken condition of the stone. The quarry, therefore, presents four and a half feet of good Dayton limestone. The Ni-

agara cap is here unfossiliferous as far as known. The Dayton limestone contains corals and orthocerites. Between the Clinton strata and the Dayton limestone is a bed of blue marl, 9 in. thick, which is referred to the Clinton Group. It contains large crinoid beads, *Orthis biforata, var. lynx*, and various minute forms not known elsewhere in the series. The Clinton Group proper has furnished a pygydium referred, doubtfully perhaps, to *Illænus Madisonianus*. The marl is in this paper called Beavertown marl.

CENTREVILLE QUARRIES.

Centreville, eight miles south of Dayton, is situated on an outlier of stone, composed of rocks belonging to the Clinton and Niagara groups. In some places that division of the Niagara Group known as the Dayton limestone or "marble" approaches within a few feet of the surface of the ground, and hence gives rare opportunities for good and readily worked quarries.

Allen's Quarry.

Several years ago, shortly after the construction of the Cincinnati Northern railroad, a quarry was opened on the farm of John E. Allen, about a half a mile east of Centreville. This quarry is probably the most easily worked and most accessible (for purposes of transportation) in the county. The Clinton rock is here of a pinkish or often dirty white color. It is exposed only by the removal of the overlying Niagara stone, or by the cutting of ditches. Yet many and often rare fossils have been found here. *Orthis Daytonensis*, with both valves preserved, has been discovered. A thin seam of bluish clay, between the Clinton and Niagara stone, furnished the large *Calymene*, to be described later. This clayey layer has not yet shown any of the curious little fossils found in the marl at Huffman's Quarry, although apparently its stratigraphical equivalent.

Beginning with the base of the Niagara exposure, the courses of Dayton stone run as follows: a 16, 18½, 6, 3½, 2¾, 4, 4¾, 2¼, 4¼ and a 1¼ in. course. Comparing these courses with those at Huffman's Quarry, it will be noticed that the 16 in. course corresponds to the 20 in. course of that quarry, and like it is divided into smaller layers: in this case into a 4 in. layer below and a 1½ in. layer above, the intermediate divisions, if any, not having been noted. The 18½ in. and 6 in. layers also correspond very nicely to the equivalent divisions

of the 26 in. layer in the other quarry; and the $3\frac{1}{2}$ in. and $2\frac{3}{4}$ in. layers might be combined so as to correspond to the 7 in. layer. Above this point comparisons would perhaps prove treacherous. Above the Dayton stone proper are found shaly layers, 50 in. and 9 in. thick, which do not sufficiently approach the crystalline character of the Dayton stone to be classed with it.

MISCELLANEOUS QUARRIES.

In addition to the quarries just mentioned, one or two others are worthy of at least a slight reference in this paper.

Fauver's Quarry.

About two miles north of Dayton, some distance west of the Covington pike, is a quarry which displays both the Clinton and Niagara groups. The quarry presents some peculiar features which will be made a special object of investigation for the next paper. The Clinton ends above in a layer of blue clay, succeeded by a number of courses of Dayton limestone, none of which attain any great thickness. The blue clay layer, besides the usual fossils of the Clinton Group, has also furnished a specimen of *Eichwaldia reticulata*, Mr. E. M. Thresher being the collector.

Fair Haven Quarry.

In Preble county, half a mile north of the village of Fair Haven, in a stream entering Four Mile Creek, a quarry has been opened, giving an exposure of the Clinton. Here there have been found numerous corals so far not known elsewhere in this State, and also the usual Clinton forms. Among others, a form of *Clathropora Clintonensis*, with unusually large oval openings (passing entirely through the bryozoum and thus forming the branches of the reticulations,) deserves special mention. A species of *Ptychophyllum*, in a fine state of preservation, occurs here; a similar, if not identical form, being found at Allen's Quarry. The exposure does not give a complete section, but over four feet of the Clinton Group are exposed.

About two miles north, along Four Mile Creek, another quarry has exposed the higher strata of the Niagara group. Its peculiar feature is a seam of cherty limestone, about nine inches thick, containing *Atrypa reticularis* in well preserved specimens. No other fossils have so far been noticed.

PALEONTOLOGY.

The Clinton Limestone of Ohio is very fossiliferous. The fossils, however, are often difficult to obtain on account of the hardness of the rock and its irregular fracture, when submitted to the blows of a geologist's hammer. For the same reasons the identification of gasteropods becomes extremely difficult, since their apertures are scarcely ever seen. In one form alone are they of common occurence, *Cyclonema bilix;* this fossil is of rather frequent occurrence in the upper, shaly part of the group, from which it sometimes weathers with the neatness of Lower Silurian fossils in this State. Some forms of brachiopods preserve their outlines very indistinctly. This is true of *Orthis flabella* and the small form I have ventured to call *O. elegantula, var. parva.* Others are found only as single valves firmly held by the rock so that only one face, the external or internal, is presented. On this account it is difficult to associate dorsal with ventral valves, internal with external features. A few forms, however, occurring in the higher, more shaly strata, are frequently found well preserved, with both valves connected. Such are *Orthis hybrida*, *O. elegantula*, and *Rhynchonella scobina*. *O. biforata f. Clintonensis* and *Triplesia Ortoni* most frequently are found as fragments embracing that portion of the valves surrounding the beaks; these fragments show both the external and internal features. They are also, although not as frequently, found as entire shells, with both valves united. *Eichwaldia reticulata*, *Orthis fausta*, and *Meristella umbonata*, the last from the middle of the formation, have all been found as entire shells. The trilobites are usually found as fragments, the heads and tails being disconnected. In *Illænus* the movable cheeks and glabellæ are thus found separated. In only one specimen of *Dalmanites Werthneri* the intermediate articulations of the thorax were discovered. The association of glabellæ and pygidia, therefore, is somewhat difficult. Still with all these failings, the fossilized forms of the Clinton Group deserve careful study, and to the careful and painstaking collector they will form one of the most productive fields of labor in the State.

The fossils of the Clinton Group differ from the remains of the superposed Niagara formations of the State in this important particular, that, whereas the latter are most frequently found in the form of casts, the former almost always present the external features. Hence they are more readily determined and their structure can usually be easily studied by means of microscopic sections. In the following pages a full ac-

count will be given of the *Brachiopoda* and *Lamellibranchiata* of the group, as far as studied. To this are appended partial accounts of the *Gasteropoda* and *Trilobita* of the same. The next paper will contain a continuation of the account of the latter groups, with a study of the bryozoans and corals of the group. The latter present a few features of special importance in the identification of the stratigraphical relations of this group.

Great pains have been taken in the identification of specific forms, and new species have been formed only with reluctance, and when there seemed to be an absolute necessity for such a course. Nevertheless quite a large number managed to creep in. Of these the most interesting are the series of forms which have so far seemed characteristic of that portion of the Clinton Group, here called the Beavertown marl. They are to be specially noticed for their small size, being accompanied with only a few larger species.

If the writer has anywhere been deceived in his judgment, he would be glad to receive such information as would be useful in correcting the same, since upon the correctness of the identification of the fossil forms must depend the correctness of all discussions as to the stratigraphical relations of the Clinton Group of Ohio.

In the description of fossil forms the nomenclature used by Hall and Meek has been adopted, and where species are identified with, or described as closely related to forms already published by these or other authors, the description of Ohio forms has been as far as possible adapted to the original description. However, no statement has been repeated which is not fully vouched for by specimens on hand, and conformity means only an acknowledgement of the excellence of the descriptions taken as a model.

Most of the species described in this paper may be found in the writer's private collection. Valuable assistance, however, has been afforded by numerous friends, both in the loan of specimens and books, as well as in such general information as has proved valuable from time to time. Among others, the writer feels specially indebted to Mr. E. M. Thresher and Mr. Geo. Caswell, of Dayton—both active collectors of the Clinton fossils near that city. He also wishes to express his appreciation of the kindness and interest shown him by Prof. Edward Orton, of the Ohio Geological Survey, a man of eminent ability, and whose carefui, painstaking work has justly won him a place among the most honored of American geologists.

Brachiopoda.

I.	Leptæna prolongata,	n. sp.
II.	Strophomena patenta,	Hall.
III.	— rhomboidalis,	Wilckens.
IV.	Orthis biforata, var. lynx. f. reversata.	
V.	— biforata, var. lynx. f. Daytonensis.	
VI.	— flabella,	Sowerby.
VII.	— hybrida,	Sowerby.
VIII.	— elegantula,	Dalman.
IX.	— elegantula, var. parva,	n. var.
X.	— fausta,	n. sp.
XI.	— Daytonensis,	n. sp.
XII.	Meristella umbonata,	Billings.
XIII.	Triplesia Ortoni,	Meek.
XIV.	———triplesiana,	n. sp.
XV.	Rhynchonella scobina,	Meek.
XVI.	Zygospira modesta,	Hall.
XVII.	Atrypa nodostriata,	Hall.
XVIII.	Eichwaldia reticulata,	Hall.

The Brachiopoda of the Clinton Group of Ohio seem to have their nearest relatives in the Niagara formations of other States. *Eichwaldia reticulata* is characteristic of the Waldron beds of Indiana. *Orthis hybrida* and *O. elegantula* are widely distributed Niagara forms. *Orthis flabella* and *Atrypa nodostriata* recall the Niagara fossils of New York. *Rhynchonella scobina* is closely related to *R. neglecta*, a Niagara fossil of considerable distribution. *Leptæna prolongata* recalls *L. transversalis* of New York. *Orthis fausta* finds its nearest relative, perhaps, in *O. Nisis*, of Kentucky strata, equivalent to Niagara formations. *Meristella umbonata* is found in the Middle Silurian of Anticosta. *Strophomena patenta*, however, is found in New York, in rocks undoubtedly Clinton. Three species, *Strophomena rhomboidalis*, *Orthis biforata var. lynx*, and apparently also *Zygospira modesta* extend from the Lower Silurian into the Clinton rocks of Ohio.

Of these, *Strophomena rhomboidalis* and *Orthis biforata, var. lynx*, have a great range vertically. *Strophomena patenta* differs from the New York types of this species in the finer and more numerous radiating striæ. *Zygospira modesta*, as stated, has its relations in lower strata. The testimony of the other fossils seems to be more or less decidedly in favor of a relationship with Niagara forms.

GENUS LEPTÆNA, Dalman.

I. LEPTÆNA PROLONGATA, *sp. n.*

(*Plate XIII, Figs.* 5 *a, b.*)

Shell of medium size, concavo-convex, semi-oval; hinge line prolonged, exceeding the width of the shell, lateral extremities acutely angular.

Ventral valve alone known, very convex, highest elevation at about one third the distance from the beak to the anterior margin, thence curving rapidly towards the anterior margin, and far more so towards the posterior margin or hinge line, which is inflected. There is a tendency towards a slight mesial elevation.

Surface marked by fine, close striæ, some of which are more prominent, the spaces between being puncto-striate. Interior of shell also striated in the same direction as the exterior surface, the reticulated structure of *L. transversalis* not observed.

This species is closely related to *L. transversalis*, from which it differs in its larger size, the lateral prolongation of the shell, especially along the hinge line, absence as far as known of reticulations among the interior striæ, and by the tendency towards a mesial fold. From *L. sericea* it can be distinguished by its great convexity from the anterior towards the posterior regions. (The specific term is intended to suggest the lateral prolongation of the shell.)

Length, 13 mm.; breadth, 25 mm.; convexity of the ventral valve, 5 to 6 mm.

Locality and position. Soldiers' Home, Clinton Group.

GENUS STROPHOMENA. Rafinesque.

II. STROPHOMENA PATENTA, Hall.

Shell described in Ohio Pal. Vol. II.

Locality and position. Soldiers' Home Quarries, Clinton Group; common.

III. STROPHOMENA RHOMBOIDALIS, Wilckens (sp.).

Described in Ohio Pal. Vol. II.; variable.

Locality and position. Soldiers' Home and Huffman Quarries, Clinton Group.

GENUS ORTHIS, Dalman.

ORTHIS BIFORATA, var. LYNX, *Von. Buch.*

IV. forma *reversata.*

(*Plate XIII, Fig.* 7.)

Shell of the type known as var. *lynx*, especially those forms which show a greater number of plications on the mesial fold and in the sinus. The name given to the form here described is expected to have only a local use to distinguish it from the variety *lynx*, as described and figured in the Ohio Geological Reports from the strata of the Cincinnati formations. Typical specimens of the different varieties of *O. biforata* from the Lower Silurian formations of Ohio have an odd number of plications in the mesial sinus, and an even number on the mesial fold. Thus var. *lynx* has typically three in the sinus and four on the fold. When more than this number appear, the typical plications are the stronger. Typical specimens of *O. biforata* var. *lynx* in the Upper Silurian formations (Clinton Group), in the two forms known to me, have an even number of plications in the mesial sinus, and an odd number on the mesial fold. In the form *reversata* the plications branch frequently, but the typical arrangement remains clearly defined. Although these distinctions are not expected to be of value elsewhere, they are too well defined and of too much interest in our local formations, not to be noted.

Shell attaining a fair size, the dorsal valve a little larger; shell wider than long, with a sub-graduate outline; no very gibbous forms have as yet been found; hinge line less than the greatest breadth of the valves; cardinal extremities obtusely angular; lateral margins rather sinuous near the hinge line, rounding to the front, where it is somewhat sinuously rounded at the junction of the mesial sinus and fold. Beaks nearly equal, incurved and approximate, sometimes almost touching; cardinal areas nearly equal.

Dorsal valve more convex than the ventral, its greatest convexity being near the middle. Mesial fold rather rounded, arising near the beak, becoming more prominent as it extends forward, with rounded sides; beak projecting beyond the hinge margin, strongly incurved; cardinal area directed backward, somewhat incurved. Foramen broad, triangular and not closed by the cardinal process.

Ventral valve with a mesial sinus, beginning near the beak, ex-

tending forward, terminating in a rounded projection which continues the curvature of the shell and thus produces a sinuous outline for the front edge of the shell. Surface of the valve rounded into the moderately concave sinus. Beak less strongly incurved than that of the dorsal valve. Cardinal area incurved and directed backward, less, however, than that of the other valve. Foramen triangular, wider than high; hinge teeth moderately prominent and trigonal; muscular cavity oblong, little more than one third the length of the shell, lateral margins parallel, well defined by the dental ridges. On either side of this cavity are a number of short striæ, which are arranged in longitudinal lines following about the direction of the plications.

Surface of each valve with rounded, radiating plications, from 24 to 36 in number, of which four to six occupy the mesial sinus, and five to seven (in one specimen ten or eleven) the mesial fold. In the sinus two plications begin at the beak, two additional ones are immediately added, and later one or two more at one third or one half the length of the shell from the beak. On the mesial fold three plications originate at the beak, to which two more are added at one fourth the length of the shell from the beak; later two more appear and in one specimen in hand ten or eleven plications are more or less distinctly shown. The plications in the sinus and on the fold branch in all specimens as described above; the lateral ones, 10-15 in number, are almost always simple. Lines of growth not shown in the specimens found. Well preserved specimens under the microscope show numerous minute granules, arranged in regular rows across the plications.

Length of the specimen figured, 24 mm.; breadth, 28 mm.; hinge line, 21 mm.; convexity, 18 mm.; breadth of largest specimen, 37 mm. Comparing this description with that given by Meek, in Pal. Ohio, Vol. I., it will be found to be about the same as that of var. *lynx*. (The name of the form is intended to suggest the fact that the odd and even number of mesial plications are found on valves opposite to those on which they occur in Lower Silurian forms, as though the shell had been *turned about.*)

Locality and position. Throughout the Clinton Group. Found entire in the Beavertown marl, generally in fragments in the rest of the group. Soldiers' Home, Centreville, Huffman's Quarries.

It may be interesting to notice in this connection that all the forms of *Orthis biforata* from the upper Niagara formations of Ohio, which I

have seen, belong to a smaller type of the var. *lynx*, and are characterized, like our Clinton specimens, by an even number of plications in the sinus, and odd number on the mesial fold.

V. Forma *Daytonensis*.

(*Plate XIII, Fig.* 8.)

This is another form belonging to the forms typified by the varieties of *O. biforata*, found in the Cincinnati formations. They bear considerable resemblance to the young of var. *lynx*, and in one case, having the hinge line greater than the breadth of the shell, it varies somewhat in the direction of var. *acutilirata*. The name is expected to have only a local use for the Clinton forms which have two plications in the mesial sinus, and three simple ones on the fold, all of which seem to originate at about the same distance from the beak.

Shell of small size, wider than long, with a subquadrate outline, hinge line usually shorter than or equaling the breadth of the valve, in one specimen exceeding it in size. The shells have their outline indistinctly preserved and are found only as single valves showing their exteror surface.

Ventral and dorsal valves with sinus and fold rounded, the plications also more rounded than those of Lower Silurian formations, simple.

These specimens could perhaps be considered as the young of the form *reversata*, were it not for the simple plications on both fold and sinus, which remain simple where on the corresponding places of the other form there would be several additional plications intercalated.

Length of medium sized specimen, 12 mm.; breadth, 18 mm.; convexity, as well as can be determined by a comparison of different single valves, 9 mm. Breadth of largest specimen, 24 mm. (The name of the form is taken from the locality where it is most frequent.

Locality and position. Soldiers' Home, Clinton Group.

VI. ORTHIS FLABELLA, *Sowerby*.

(*Plate XIII, Figs.* 12 *a, b.*)

Shell semi-oval ; hinge line equal to the breadth of the valve or generally a little less. Shell wider than long, the dorsal valve much more convex than the other, very variable.

Dorsal valve very convex, the greatest convexity being near the beak ; beak much elevated, incurved.

Ventral valve flattened, with a shallow mesial sinus, more marked along the posterior half of the shell, towards the beak ; beak but slightly elevated.

Surface marked by twenty to twenty-four simple, strong, low, rounded, almost straight plications, equal to the broad, flattish spaces between them in width.

From the form as described above there are many variations. The middle plication of the dorsal valve frequently manifests a tendency towards becoming more elevated and almost forming a low carina towards the beak ; the other plications becoming more indistinct as they approach this point. They may also become more angular, more numerous, approaching thirty in number, and the spaces between them may become even narrower than the plications. Again, in a few specimens they divide dichotomously towards their extremities. The shells also vary considerably in size, from 18 to 43 mm. in breadth. Faint concentric striæ may also appear in the depression between the plications ; lines of growth are still more rare. The anterior and lateral margins of the shell are rarely well defined in our specimens.

Length, 18 mm.; breadth, 26 mm.; convexity, as nearly as can be determined by comparison of the separated valves, 8 to 9 mm., being accounted for mainly by the great convexity of the dorsal valve.

The shell has been found only in the form of separated valves, the exterior surface exposed, the cardinal area invisible ; however, the few simple plications usually equaling the flat depressions between sufficiently determine this species.

Locality and position. Soldiers' Home Quarries, Clinton Group; very common in places.

VII. Orthis hybrida, *Sowerby*.

(*Plate XIII, Figs.* 10 *a*, *b*.)

Shell lenticular, greatest diameter at one third the length of the shell from the beak, wider than long ; valves nearly equal, hinge line about half the width of the shell.

Dorsal valve convex, evenly rounded, beak less elevated than that of the ventral valve, cardinal area smaller, extending the length of the hinge line.

Ventral valve convex, with a broad, undefined depression extending from near the centre to the anterior margin; beak a little incurved, cardinal area directed backwards, incurved. Owing to the depression along the anterior portion of the ventral valve, the shell has a sinuous outline in front.

Surface marked by fine, close, branching striæ, which are arched upwards along the postero-lateral margins; radiating striæ crossed by several lines of growth. Concentric striæ not distinguishable in the specimens at hand.

Length, 17 mm.; breadth, 19 mm.; convexity, 8 mm.; hinge line, 10 mm.

Locality and position. Soldiers' Home Quarry, in the upper, shaly courses of the Clinton Group.

VIII. Orthis elegantula, *Dalman.*

(*Plate XIII, Figs.* 11 *a, b.*)

Shell semi-oval; hinge line shorter than the width of the shell, exceeding the length of the cardinal area.

Dorsal valve almost flat, with a shallow depression extending from the beak to the anterior margin; more marked near the beak; beak not incurved.

Ventral valve convex, extremely elevated towards the beak; beak much exceeding that of ventral valve in length, and incurved over the cardinal area.

Surface marked by fine radiating striæ, branching, curved upwards along the lateral and posterior margins; crossed by lines of growth, and fainter concentric striæ.

This species may be readily distinguished from *O. hybrida* by the flat dorsal valve, and shallow depression extending from the beak to the anterior margin, also by the more quadrangular outline of the shell.

Length, 16 mm.; breadth, 17 mm.; convexity, 4 mm.; hinge line, 10 mm.

Locality and position. Soldiers' Home and Centreville Quarries, in the upper courses of the Clinton Group.

IX. var. *parva*, or young.

(*Plate XIII, Figs.* 17 *a, b.*)

Among the specimens of *Orthis* collected at the Soldiers' Home Quarries occur great numbers of a small form resembling *O. elegantula*. The ventral valve is exceedingly convex and the surface is marked by fine, numerous, indistinctly preserved striæ, being plainest at the lateral and anterior margins of the valve. The beak is very prominent and incurved.

An ordinary sized specimen of the ventral valve measured gave a length of 6 mm.; breadth, 7 mm.; convexity, 3 mm. The largest specimen observed does not exceed 10 mm. in breadth.

The variety occurs frequently in the limestone of the Clinton Group, whereas the species described above seems confined to the upper, shaly courses. The main reasons for separating it from the species are its smaller size, greater convexity, and different location. If not the young of *O. elegantula* it is certainly a well marked variety. Its general appearance is somewhat like that of *O. pisa* of New York strata, but our shell does not have both valves connected and the presence of an occasional dorsal valve having a low mesial depression, apparently to be associated with the ventral forms, would preclude such a determination. For the present it may be considered a variety of *O. elegantula.*

Locality and position. Widely distributed throughout the Soldiers' Home Quarries, in all except the uppermost layers of the Clinton Group.

X. ORTHIS FAUSTA, *sp. n.*

(*Plate XIII, Figs.* 15 *a, b, c, d*; *and Figs.* 16 *a, b.*)

Shell of medium size or often less, wider than long; hinge line not equaling the width of the shell; lateral margins rounded in front, posteriorly incurved, frequently expanding at the hinge line just enough to leave the postero-lateral margins extend a slight distance beyond the incurved portion of the same, like little ears. Convexity of the valves almost equal, that of the ventral valve being slightly the greater.

Dorsal valve convex, with a distinct mesial sinus extending from the beak to a point about one third the distance from the anterior margin, where it vanishes; the greatest convexity lies a little behind the

middle, on either side of the mesial sinus. Beak slightly elevated, scarcely incurved; foramen broad-triangular, width equal to twice the height. Cardinal process small, laterally compressed, not filling the foramen, in a line with the base of the cardinal area; cardinal area moderate, one third that of the ventral valve, equaling the hinge line, directed backwards, arched. Postero-lateral regions of the valve moderately compressed.

Ventral valve more convex, its greatest convexity about two-fifths the distance from the beak, sloping regularly to the lateral and anterior margins. Beak prominent, incurved, having two or three times the elevation of the dorsal valve; cardinal area corresponding, directed obliquely backwards, arched; foramen triangular.

Surface marked by 40 to 50 radiating striæ, which increase by frequent intercalations, and are crossed by distinct concentric striæ, giving the surface a beautifully ornate appearance, which will serve to readily distinguish it from the other species of *Orthis* found here. (Figs. 15 *a, b, c, d.*)

A form of this species occurs having the general shape and characteristics of the typical specimens, but the plications are more angular, sometimes almost acutely ridged, and crossed by concentric striæ, more closely arranged, and also much less distinct, not producing the ornate appearance characteristic of the typical form. For this reason I was once inclined to separate them under a different name, *acuto-plicata*, but at present I am of the opinion that they are not sufficiently distinct to be placed even under a varietal name. (Fig. 16 *a, b.*)

Length of a specimen, 17 mm.; breadth, 21 mm.; convexity, 9 mm.; varying from this to specimens with a convexity of only 6 or 7 mm.

This species seems to be a form intermediate between *Orthis insculpta* and *O. bella-rugosa* of the Lower Silurian strata, and *O. Nisis* of the Niagara group of Kentucky. It differs from the last in the much smaller elevation of the ventral beak; from the second, in the coarser and broader appearance of its radiating striæ, the absence of an incurved anterior margin, and by the greater curve of its ventral beak; from the first it is chiefly distinguished by greater size and more numerous striæ.

Locality and position. Soldiers' Home Quarries, Clinton Group; the typical forms, in the upper part of the group; the variety with more acute plications, in the lower portions of the same.

XI. Orthis Daytonensis, *sp. n.*

(*Plate XIII, Figs.* 13 *a, b, c, d.; Figs.* 20 *a, b; and Fig.* 21.)

Dorsal valve wider than long, very convex, greatest convexity being just behind the middle, thence sloping almost equally on all sides, except toward the postero-lateral regions, which are somewhat compressed; a faint mesial sinus towards the beak. Cardinal area narrow, foramen broadly triangular, cardinal process narrow, compressed laterally, and situated beyond a line connecting the lower edges of the cardinal area, or on the line itself; not filling the foramen.

Ventral valve flattish, its greatest convexity one fourth the distance from the beak or even closer; thence sloping towards the postero-lateral extremities and the anterior margin, causing the anterior portion of the valve to be depressed, and leaving that portion of the shell extending from the beak to about the middle of the lateral margins elevated above the other portions of the valve.

The interior of a ventral valve found will be sufficiently explained by Fig. 20 b, of Plate XIII. A single specimen with both valves united has been found presenting the characteristics of the valves just described, and furnishes my authority for uniting them under the same species. But as a curious matter of fact most of the ventral valves have been found at Allen's Quarry, and all the dorsal valves at the Soldiers' Home Quarries. The entire specimen is smaller in size than most of the single valves found.

Surface marked by 60 to 90 fine, radiating striæ; the branching is frequent and by intercalations. Concentric striæ distant from each other about the space between the radiating striæ, or more, giving sometimes the appearance of quadrangular punctæ between the striæ; concentric striæ usually best preserved in the spaces between the radiating striæ, often not very plain on the striæ themselves.

Length of a dorsal valve, 17 mm.; breadth, 21 mm.; convexity, 5 to 6 mm. Length of a ventral valve, 21 mm.; breadth, 26 mm.; convexity, 4 to 5 mm. Length of the only complete shell found, 18 mm.; breadth 23 mm.; convexity, 8 mm.; the relative elevation of the beaks in this specimen may be understood by examining Fig. 21, of Plate XIII.

Locality and position. Allen's and Soldiers' Home Quarries, Clinton Group.

GENUS MERISTELLA, Hall.

XII. MERISTELLA UMBONATA, *Billings* (sp.).

(*Plate XIII, Figs. 2 a, b.*)

Shell elongate ovate, the sides forming a continuous curve from the umbo of the ventral valve to the front margin, with the exception of a very slight inward curve at the hinge extremities, not at all resembling those of the Ohio forms of *M. cylindrica*; front margin rounded.

Dorsal valve convex, greatest elevation at one third the distance from the beak, thence obtusely rounded towards the beak which is concealed by that of the ventral valve.

Ventral valve strongly convex, forming a continuous curve from the anterior margin to the beak, which is spirally incurved upon the beak of the dorsal valve, which it more or less conceals. The ventral valve considerably elevated above the beak of the dorsal, more so than would be indicated by the figures accompanying this description.

Surface smooth, the concentric striæ indistinct.

Length of dorsal valve, 14 mm.; of ventral valve in the same specimen, 17 mm.; breadth, 14 mm.; convexity, 12 mm. Length of dorsal valve in a small specimen, 10 mm.; ventral valve, 12 mm.; breadth, 8 mm.; convexity, 8 mm.

The first inclination was to place these specimens under *Meristella cylindrica*, but several reasons will not permit this: the size of the specimens is smaller, the elevation of the ventral valve is greater, the length of the shell is relatively smaller as compared with its breadth, and considered as young of *M. cylindrica*, their convexity is too great. On the other hand they are of the same size and outline as *M. umbonata*. Associated with the ordinary forms are also separated valves, broadly ovate in outline and more nearly resembling those forms described by Billings under the specific term *Prinstana*. Since the writer is of the opinion that this species is only another form of *M. umbonata*, its apparent occurrence in the same strata in Ohio with the form just described, seems to him an additional proof of its identity.

Locality and position. Soldiers' Home Quarry, Clinton Limestone. Specimens from this locality were kindly loaned by Mr. George Caswell, of Dayton.

GENUS TRIPLESIA, Hall.

XIII. TRIPLESIA ORTONI, *Meek.*

Described in Ohio Pal. Vol. I.

Locality and position. Soldiers' Home and Centreville Quarries, Clinton Group; the upper "shovel ends" are frequent in the upper shaly courses of the Group.

GENUS ———

XIV. ——— TRIPLESIANA, sp. n.

(*Plate XIV, Figs.* 13 *a, b; and Fig.* 14.)

The generic relations of the following shell I have been unable to determine satisfactorily, although the specimens are in a moderately good state of preservation. A specific name is merely suggested for the local use of collectors, and a description appended to give notification of at least the existence of such a shell. The specific name is intended to suggest its similarity in appearance to certain very flat forms of *Triplesia Ortoni* in which the cardinal area is not much developed.

Shell subquadrate, or rounded anteriorly and more oval in outline, medium or larger in size; cardinal area scarcely developed, very narrow, but apparently equalling the hinge line. Beaks approximate, with about the same elevation, scarcely elevated above the hinge line, not prominent.

One valve of the shell has a low mesial elevation of moderate breadth, corresponding to a mesial sinus on the other valve, which is shallow but equally distinct. The comparative breadth of the mesial fold and sinus, considering the general contour of the shell, although suggesting *Triplesia Ortoni*, is dissimilar. In other respects it suggests to me a strophomenoid shell.

Surface marked by broad, radiating, scarcely evident folds, and similar concentric elevations of growth, in addition to which, very fine, fibrous, radiating striæ are visible in the more or less silicified shell. Lateral margin meeting the hinge line at little more than an angle of ninety degrees, rounded anteriorly, slightly projecting at the middle.

Length, 27 mm.; breadth, 29 mm.; convexity, 12 mm. Length of another individual, 28 mm.; breadth, 30 mm.

Locality and position. Soldiers' Home Quarry, in the middle of the Clinton Group.

GENUS RHYNCHONELLA, Fisher.

XV. RHYNCHONELLA SCOBINA, *Meek*.

Described in Ohio Pal. Vol. I and II.

Locality and position. Soldiers' Home, Huffman, and Centreville Quarries, Clinton Group; common.

GENUS ZYGOSPIRA, Hall.

XVI. ZYGOSPIRA MODESTA, *Say* (*sp.*).

(*Plate XIII, Fig.* 6.)

Described in Ohio Pal. Vol. I., and mentioned as occurring in the Clinton Group. I have seen no specimens which could be referred without doubt to this species unless it be a dorsal valve of the following description.

Dorsal valve subquadrate orbicular; beak not elevated; marked by about twenty simple plications; with a shallow mesial sinus, occupied by three plications, the middle plication larger, the lateral ones smaller than the plications immediately adjacent.

Length, 7 mm.; width scarcely larger.

Locality and position. Beavertown marl, Huffman's Quarry, Clinton Group.

GENUS ATRYPA, Dalman.

XVII. ATRYPA NODOSTRIATA, *Hall*.

(*Plate XIII, Fig.* 9.)

Shell described in Ohio Pal. Vol. II.

A small species of Atrypa referred here occurs sparingly, of the following description.

Shell oval, marked by plications, branching near the middle of the shell. Mesial sinus on the ventral valve plainly defined by the bordering plication on each side, containing three to five plications. Dorsal valve with mesial elevation, well defined by a more or less sharp sinus on each side, which is more marked towards the beak.

Length, 11 mm.; breadth, 11 mm.; convexity, 6 mm.

Locality and position. Soldiers' Home, Clinton Group.

GENUS EICHWALDIA, Billings.

XVIII. EICHWALDIA RETICULATA, *Hall.*

(*Plate XIII, Figs.* 4 *a, b.*)

Shell broadly triangular ovate, gibbous, cardinal slopes flattened.

Ventral beak small, acute, flattened on the back, closely incurved, the sinus extending from the beak to the anterior edge, broad, distinct.

Dorsal valve more convex, beak obtuse, strongly incurved, a low, fairly defined mesial fold extending from the beak to the anterior margin.

Surface covered by fine, hexagonal, reticulate markings, largest along the antero-lateral slopes, and decreasing in size towards the sinus and posterior regions. A small space near the ventral beak is destitute of markings.

Length, 8 mm.; breadth, 8 mm.; convexity, 6 mm.

Locality and position. Fauvers' Quarry north of Dayton, Clinton Group. Collection of Mr. E. M. Thresher.

LAMELLIBRANCHIATA.

I.	Pterinea brisa, - - - - -	Hall.
II.	Grammysia Caswelli, - - - -	n. sp.
III.	Cypricardites ferrugineum -	Hall and Whitfield.
IV.	Nucula minima, - - - - - -	n. sp.

The *Lamellibranchiata* of the Clinton Group of Ohio are but few both in the number of species and in the frequency of their occurrence. *Pterinea brisa,* if correctly identified, adds another link connecting this formation with the Niagara Group of the West. It occurs also at Waldron, Indiana, and Bridgeport, Illinois.

GENUS PTERINEA, Goldfuss.

I. PTERINEA BRISA, *Hall.*

(*Plate XIII. Figs.* 14 *a, b.*)

Left valve alone found. Body of the shell obliquely sub-ovate, extremely inequilateral; anterior wing moderately extended; sinuate at its junction with the body; posterior wing acutely extended a little beyond the posterior extremity of the shell; umbo prominent, beak rising a little above the hinge line, muscular impression in right valve unknown from want of specimens.

Surface marked by strong, radiating striæ, and less conspicuous concentric striæ.

The intercalation of radiating striæ in some cases gives rise to an appearance similar to the dentations and groovings figured in the Indiana reports, but not identical with them. The concentric striæ also are not so prominent. The crystallized character of our specimens will, perhaps, account in part for these discrepancies. Fig. 14 *b* represents a specimen with fewer radiating striæ, referred here.

Length, 16-17 mm.; height, 10-11 mm.; convexity of the left valve, about 2 mm.

Locality and position. Soldiers' Home Quarries, Clinton Group.

GENUS GRAMMYSIA, De Verneuil.

11. GRAMMYSIA CASWELLI, *sp. n.*

(*Plate XIV, Figs.* 12 *a, b.*)

Shell small, transversely sub-ovate; umbonal regions gibbous, anterior regions likewise; height at the beaks equalling about five-eights of the length. Anterior end sloping abruptly from the beaks above, with a distinctly concave outline, to the lower end of the lunule, where it is met by the rounding base, forming more or less an angle at their junction; base forming a broad semi-elliptic curve; posterior end more compressed, the specimen at hand being too imperfect to determine whether it gaps at this extremity, although it is presumed to do so a little from the curvature of the better preserved valve; posterior end rounded, then curving upward and quite rapidly forward almost merging into the hinge line.

Cardinal margin indistinctly preserved, judged to be nearly horizontal, slightly concave in outline, and inflected along its entire length, forming a well defined escutcheon; lunule distinct, with an ob-ovate outline, quite deep. Beaks prominent, strongly incurved, obliquely to the hinge, directed a little forwards, posterior umbonal slopes prominently, yet rather broadly rounded.

Surface ornamented in the cast by well-defined concentric ridges and furrows, these in the specimen at hand crossed by fine parallel lines, almost vertical, directed a little backwards, and which may be accidental rather than a special feature of the shell. Ridges strongest

anteriorly, becoming less distinct posteriorly. A portion of the shell where preserved shows the ridges far less defined than on the cast.

Length, 37 mm.; height, 25 mm.; convexity, 25 mm.

Locality and position. Soldiers' Home, Clinton Group. Collection of Mr. Geo. Caswell.

GENUS CYPRICARDITES, Conrad.

III. CYPRICARDITES FERRUGINEUM, *Hall and Whitfield.*

Species described in Ohio Pal. Vol. II.

Locality and position. Wilmington, Clinton County, Ohio, Clinton Group. To my knowledge not found elsewhere.

GENUS NUCULA, Lamarck.

IV. NUCULA MINIMA, *sp. n.*

(*Plate XIV, Figs.* 8 *a, b, c.*)

Shell (presumably the cast) very small, ovoid, gibbous above the middle towards the beaks, outline curving to the base and posterior extremity, anteriorly curving more rapidly to the beaks above. Beaks, near the anterior extremity of the shell, incurved and inclined forwards. Hinge line at one-third the distance from the beak to its posterior extremity supplied on each side with a narrow fold, directed backwards, making a small angle with the hinge line, and vanishing at one-third the distance from the posterior extremity in the depressed regions formed by the raised postero-umbonal regions.

Near the beak on each valve are three to four radiating grooves, which are characteristic of this species and are evident under the microscope.

In addition to these grooves are three more or less clearly defined pits, one being placed in the anterior groove near the beak, and the two others in the second groove, one on each side, and at a greater distance from the beak. Along the hinge line, anterior to the beaks, are two or three more or less distinct crenulations, which appear a little like plications originating in the lunule near the beak and becoming more distinct at the hinge line.

Length, 2 mm.; height, 1.4 mm.; convexity, 1 mm.

Locality and position. Beavertown marl, Huffman's Quarry; not found elsewhere in the Clinton Group. Associated with many other

minute forms, apparently chiefly in the form of casts, among these a number of *gasteropoda*.

GASTEROPODA.

I.	Cyclonema bilix,	Conrad (sp.).
II.	Trochonema nana,	n. sp.
III.	Raphistoma affinis,	n. sp.
IV.	Pleurotomaria inexpectans,	Hall and Whitfield.
V.	Cyclora alta,	n. sp.
VI.	Strophostylus cyclostomus,	Hall.
VII.	Platyostoma Niagarense,	Hall.
VIII.	Bucania exigua,	n. sp.
IX.	Bellerophon fistello-striatus,	n. sp.

The *Gasteropoda* of the Clinton Group, identified with previously described forms, are too few to form any great basis of comparison, stratigraphically. *Cyclonema bilix* ranges from the Lower Silurian into the Upper. *Strophostylus cyclostomus* is found also at Waldron, Indiana. *Platyostoma Niagarense* differs in size and expansion at the aperture from typical specimens, but its connection with them seems undoubted. At any rate its deviation from the typical forms is far less than the var. *trigonostoma* of Meek, and all these forms are typical of the Niagara.

GENUS CYCLONEMA, Hall.

I. CYCLONEMA BILIX, *Conrad* (sp.).

Shell described from the Lower Silurian in Ohio Pal. Vol. I.

Locality and position. Centreville and Soldiers' Home Quarries, frequent in the upper courses of the Clinton Group.

GENUS TROCHONEMA, Salter.

II. TROCHONEMA NANA, *sp. n.*

(*Plate XIV, Fig.* 16.)

Shell oblong, the height about twice the breadth, in the specimen figured the carina being a little more prominent than is there indicated. Volutions about three, increasing rapidly in size, the last disproportionately so, forming the larger bulk of the shell, almost equaling two-thirds the height. Shell thin; it is impossible to trace the suture line,

but there is a carina where the volutions may be supposed to meet, this carina is distinctly grooved along the latter half of the last volution where it approaches the aperture of the shell; above the carina is a low shallow groove which in the last volution spreads so as to cover the entire volution. Surface smooth. Shell probably in the form of a cast.

Height, 3 mm.; breadth, 1.5 mm.; height of aperture, .9 mm. (?) breadth of aperture, .35 mm. (?) above, narrowing to .23 mm. (?) below. The measurements given for the aperture are liable to error, although there seem to be slight grooves and elevations at the close of the last volution, which look like an elongated aperture.

Locality and position. Beavertown marl, Huffman's Quarry, Clinton Group. (Name signifying dwarf.)

GENUS RAPHISTOMA, Hall.

III. RAPHISTOMA AFFINIS, *sp. n.*

(*Plate XIV, Fig.* 18.)

Shell lenticular; breadth a little more than twice the height; convexity moderate above, equally so below; volutions varying from two and a half to three and a half, with a moderate slope above, coincident with that of the spire; the last volution sharply carinate around the periphery, convex below, being more so at the umbilicus into which the slope is abrupt; suture distinct, forming a small groove between the volutions; umbilicus as wide as the outer volution; the last volution becoming transversely rhomboidal, the aperture itself not being preserved, the breadth about three times the height. Surface apparently smooth.

This species is almost in every respect identical with forms of *R. lenticularis* as known to me from the Lower Silurian formations. It is however a much smaller shell, with less numerous volutions, and apparently a distinct form.

Breadth of largest specimen, 7 mm.; height, 3 mm.; breadth of the end of the last volution, 3 mm.; height, 1.2 mm.; aperture not preserved.

Locality and position. Beavertown marl, Huffman's Quarry, Clinton Group. (Name signifying *related*, the shell being closely allied to the well known species, *R. lenticularis.*)

GENUS PLEUROTOMARIA, De France.

IV. PLEUROTOMARIA INEXPECTANS, *Hall and Whitfield.*

Shell described in Ohio Pal. Vol. II.

Locality and position. Iron ore beds of Clinton County, Clinton Group.

GENUS CYCLORA, Hall.

V. CYCLORA ALTA, *sp. n.*

(*Plate XIV, Figs.* 17 *a, b.*)

Shell very small, conoid subglobose; spire varying from two-thirds to slightly more than the diameter of the last volution; volutions three or four, increasing in size rapidly, but evenly; the last volution not so disproportionate in size to the rest of the shell as compared with the species so far described; suture deep; surface smooth; umbilicus small; aperture circular.

Height of largest specimen seen, 4 mm.; breadth, 3.5 mm. Height of a specimen of the usual size, 2 mm.; breadth, 2.75 mm. From this varying to specimens only 1 mm. broad.

This shell differs from the species of *Cyclora* so far described in its greater size, greater elevation of the spire, and the more regular increase of its volutions. Its general form approaches that of the closely related genus *Holopea.* Since the chief distinction, however, of the first genus is its diminutive size, it may be safe to refer to it also the specimens here described.

Locality and position. Beavertown marl, Huffman's Quarry, Clinton Group; not scarce (Name intended to suggest the height of the spire, as compared with other species of this genus.)

GENUS STROPHOSTYLUS, Hall.

VI. STROPHOSTYLUS CYCLOSTOMUS, *Hall.*

(*Plate XIV, Fig.* 15)

Shell transversely broad-oval. Spire moderately elevated; volutions in the specimen figured, three, a fourth having broken away; the last volution by far the largest, ventricose. Aperture not fully exposed, oblique to the axis, subcircular.

Surface marked by shallow, broad striæ and closer, finer striations crossing the volutions obliquely and in a direction opposed to them.

Diameter of volutions, measured in a plane vertical to the shell and passing through the aperture, 6, 17, and 44 mm.; elevation of the second and third volutions less than half the last.

The character and direction of the shell aperture, the relative size and position of the volutions seem to leave no doubt as to the identity of the specimen, and will at the same time serve to distinguish it from any other species of gasteropod found in Ohio.

Locality and position. Soldiers' Home Quarry, Clinton Group.

GENUS PLATYOSTOMA, Conrad.

VII. PLATYOSTOMA NIAGARENSE, *Hall.*

(*Plate XIII, Figs.* 22 *a, b; and Figs.* 3 *a, b.*)

Shell ovoid, volutions three to four, the last much increased in size, spire elevated above the plane of the outer volution, about one sixth of the height of the shell.

Apex minute, expanding symmetrically as far as the outer volution, which is ventricose, and somewhat straightened at the aperture, so as not to maintain the curvature of the coil; in one specimen marked on the upper and lower side by a groove along which the striæ are abruptly bent; peristome undulated.

Surface marked by fine undulating striæ of growth, cancellated by finer revolving striæ.

The specimens referred here are smaller in size than typical forms of this species from western localities,and they differ from them in the tendency for the last volution to lessen its rate of curvature and become somewhat straightened as it approaches the aperture. This straightened appearance is in part due to the slight expansion of the lip at the aperture. Nevertheless these variances seem too slight to give rise to any separation from the typical form under a new specific name.

Height of shell, 21 mm.; elevation of the first three volutions above the plane of the last, 3.2 mm.; greatest diameter (passing through the aperture), 26 mm.; diameter vertical to the same, 17 mm.; diameter of the second and third coils, 2.6 and 7 mm.

Locality and position. Brown's Quarry, New Carlisle, Clinton Group, kindly loaned from the collections of the Ohio State University, by Prof. Edward Orton.

In the Soldiers' Home Quarries occur specimens which have usual-

iy been referred to *Holopea*, both by collectors and writers on geology. They consist for the most part of the upper three, or three and a half volutions of a shell which seems identical with the form just described. The character of the volutions and surface striations are the same; the last volution is also expanded at the aperture, giving greater distinctness to the lip, and having the same straightening effect on the curvature of the shell at this point.

In the New Carlisle specimens, however, the upper side of the last third of the last volution is flattened above and quite evenly rounded on the sides, forming in this way a line of elevation along the upper side of the volution, where the gradual curvature of the sides meets the flattened portion above. In the Soldiers' Home specimen which is best preserved, there is no flattening along the upper plane of this last volution, but instead, there is an even curvature from the suture to the lower side, an elevation being thus formed at the umbilicus into which the side of the lower third of the volution bends abruptly.

The aperture of this specimen, therefore, is oblique to a vertical diameter of the shell, whereas, in the New Carlisle specimens the aperture seems to have its greatest diameter vertical to the shell. Other forms, however, occur at the Soldiers' Home, among which are some with deep sutures and less oblique apertures; some quite similar to the New Carlisle specimens, but much smaller; a specimen with its coils arranged somewhat like *P. plebium*, but only half its size (Fig. 3 b.); and a specimen varying to the opposite extreme, with the last volution extremely ventricose, the upper volution only moderately raised, the part towards the aperture, however, being lacking (Fig. 3a). All the forms from the Soldiers' Home differ from the New Carlisle specimens, however, in their smaller size, the New Carlisle specimens differing in turn from the typical western forms chiefly in their smaller size. All these Clinton forms differ from the western in the slight expansion of the lip at the aperture and the straightened appearance of the volutions at this point, the rate of curvature decreasing.

Specimens last described, at Soldiers' Home Quarries, Clinton Group.

(The variations here indicated will be carefully figured in the next paper.)

GENUS BUCANIA, Hall.

VIII. BUCANIA EXIGUA, *sp. n.*

(*Plate XIII, Figs.* 18 *a, b, c, d.*)

Number of volutions not known, the last alone visible, increasing rapidly in size and expanding at the aperture; the exact character of the aperture not known from want of preservation, but is presumed to be similar to that of *B. bilobatus.* The outer volution rounded on the dorsum at its origin, a mesial carina gradually developing toward the aperture near which it becomes quite distinct, in some individuals, decidedly so. From this carina the sides slope evenly to the umbilicus, which they enter with a sudden curve, forming a low, indistinct, lateral carina, by the increase of curvature. Umbilicus apparently closed, the last volution alone being visible in the specimens examined. Surface of the cast smooth, traces of the original shell, however, seem to remain in a few spots, indicating a system of striæ curving from the mesial carina obliquely backwards, these apparently crossed by other striations. The usual form of the cast, however, is smooth, the shell being entirely removed.

Measurements, on account of the imperfect preservation of the shell towards the aperture, are of little value, still the following will serve to give a general idea of the proportions of the shell. Greatest diameter of the typical specimen (Plate XIII, Figs. a, b.), 9 mm.; diameter at right angles to this, 6.2 mm.; diameter of last volution at the point where it becomes visible, 3.5 mm.; broadest part of volution preserved, 7 mm. From this they vary in size from specimens which become almost minute to some having a greatest diameter of 22 mm.

Locality and position. Beavertown marl, Huffman's Quarry, Clinton Group. (Name signifying *quite small.*)

GENUS BELLEROPHON, Montfort.

IX. BELLEROPHON FISCELLO-STRIATUS, *sp. n.*

(*Plate XIII, Figs.* 19 *a, b, c, d.*)

Shell sub-discoid; only the last volution known, increasing rapidly in size, being almost four times as large at the aperture as at the point where it first becomes visible; the increase in size is quite regular, except near the aperture where there is a moderate expansion of the vo-

lution; aperture not distinctly preserved, but apparently the aperture was dorsally sinuate, the sinuation being simple and broadly V-shaped; this, however, can not be conclusively determined. Umbilicus quite large, and deeply defined. Dorsally the curvature of the shell toward each side is even and moderate, laterally the curvature is very sudden, the curvature of the sides into the umbilicus equaling or even exceeding the dorsal curvature of the shell; by this means the umbilicus is deepened and the sides of the shell appear raised, almost carinated towards the aperture.

Surface marked by fine longitudinal striæ, of which thirteen may be counted on each side of the carina as far as the beginning of the umbilicus, these are increased by intercalations with the age of the shell. Transverse striæ in the direction of the lines of growth, the striæ on opposite sides of the carina having an angle to each other equal to that which the sides of the sinus of the aperture seem to have. A third, less distinct system of striæ, originating at the carina, seems to make about the same angle with the longitudinal striæ as the transverse striæ just described. As a result of all these striations, the surface of the shell is divided up into many minute, many-sided polygons which give the shell a beautiful appearance. This is enhanced by a low, distinct carina, slightly raised at the sides and thus becoming grooved. Along the carina only afew, indistinct, longitudinal striæ are here and there visible, there are however many fine transverse striæ, bending backward into the groove of the carina.

Greatest diameter (extending through the aperture), 11 mm.; diameter transverse to this, 9 mm. Diameter of the last volution at its beginning, 2.5 mm.; at the aperture, the diameter passing through the dorsum is 5 mm.; the one transverse to this, 9 mm. The width of the carina, .4 to .5 mm.

Locality and position. Stolz's Quarry, Clinton Group.

CRUSTACEA.

I.	Acidaspis ———, ...	
II.	Bathyurus, ———, ...	
III.	Illænus Daytonensis, . . .	Hall and Whitfield.
IV.	— Madisonianus, . . .	Whitfield.
V.	— ambiguus, ...	n. sp.
VI.	Calymene ———, ...	

VII. Calymene Blumenbachii ? . . . Brongniart.
VIII. Lichas breviceps. . . . . . . Hall.
IX. Arionellus ? ———. . . . .
X. Dalmanites Werthneri. . . . . . n. sp.

The trilobites so far studied seem to be either identical with, or closely related to Niagara forms. Hall and Whitfield, in their description of *Illænus Daytonensis*, say that "specimens having the same features have been collected from the Niagara Group of Wisconsin and Illinois." *I. Madisonianus* is found in Wisconsin; however, I am unwilling to consider this as good evidence, since the identification is based upon one specimen, and that, the pygidium. *I. ambiguus* finds a close relation in *I. insignis*, a typical, western Niagara fossil. *Lichas breviceps* agrees quite closely in all important characteristics, especially those of the pygidium, with described forms of this species from Waldron, Indiana. *Dalmanites Werthneri* is closely related to *D. vigilans* and *D. verrucosus*, also from the Niagara strata of Indiana. Of the other species not much can be said in the present state of knowledge concerning them.

GENUS ACIDASPIS, Murchison.

I. ACIDASPIS ———.

(*Plate XIII. Fig.* 23.)

A fragment of a trilobite belonging to this genus has been found, presenting chiefly the movable cheek, but also portions of the glabella.

Glabella poorly preserved; including the occipital regions its breadth, as nearly as can be determined, is equal to about one third or two fifths its length, the widest part being behind the middle, between the eyes; lateral lobes apparently three on each side, the middle and posterior lateral lobes along one side of the glabella being distinctly defined in the specimen, the third, anterior lobe, less plainly, on account of the imperfect preservation of the fossil at this point. Lateral lobes of an almost oval outline, directed obliquely forward and outward, the posterior one larger than the middle lobe, separated by a distinct furrow from the cheeks and from themselves; there is a broad groove between the lateral lobes and the glabella proper, in addition to which the furrow between the middle and posterior lateral lobes and the occipital furrow rounding behind the posterior lateral lobe bend

towards one another between the posterior lateral lobe and the glabella, which they seem to connect by means of the raised portion left between them; this connection is not altogether destroyed by the low groove which separates them. The occipital regions curve strongly downwards towards each side, behind and below the posterior lateral lobe, then slightly outward and forward. On this account the posterior margin of the glabella is considerably deflected on either side, beginning a considerable distance beneath the surface of the lateral lobe and fixed cheek, thence rising to almost the level of the glabella and again descending on the other side, being gracefully undulated in this way. The occipital furrow extends from the lower part of the posterior lateral lobe, behind this lobe, as described above, reaching a little more than one third the distance across the glabella. The slope of the rear of the posterior lateral lobe to the occipital regions below is almost vertical.

Fixed cheek divided from the movable cheek by a furrow, which between the middle lateral lobe and the anterior lateral lobe approaches closely to the furrow dividing the lateral lobes from the cheek; thence the former is gradually separated from the latter until it meets the inner margin of the eye, behind which it seems to curve and then become indistinct. Anteriorly the fixed cheek slopes rapidly downward and forward, posteriorly it curves far more rapidly downwards, incurving a little below, so that a distinct furrow seems to separate it from the occipital regions of the glabella; another furrow, starting at the junction of the glabella and fixed cheek, curves around behind the eye, separating the raised portion of the cheek between the eye and the glabella, from the posterior margin of the cheek.

Eye not preserved, judging from indications they were small, placed in a line with the rear of the posterior lateral lobes.

Movable cheek grooved near the fixed cheek, the groove following the direction of the furrow separating the cheeks; that part of the movable cheek between the groove and the furrow following the curvature of the fixed cheek. From this groove there is a gradual downward and outward curvature of the cheek, the same being true of the portions at the side of the eye. Behind the eye, there is a more sudden downward and backward curvature, the groove above mentioned extending behind the raised regions about the eye near the posterior margin of the cheeks, spreading out and becoming indistinct towards the lateral

margin of the head. The posterior and lateral margins of the cheek are distinctly raised so as to form a ridge around the cheek. From the junction of the lateral and posterior ridge a long, sharp spine extends almost directly backward, and a little downward. Along the lateral ridge of the cheek are arranged a number of short spines about one third as long as the postero-lateral spine. The lateral spines curve obliquely backwards. They are apparently almost equidistant from each other and decrease in length anteriorly. There is a lateral spine at the origin of the postero-lateral spine, from this point to a point opposite to the groove between the middle and anterior dorsal furrow 10 spines may more or less distinctly be discerned.

The general curvature of the head is semi-circular from side to side, the convexity from the anterior portion to the posterior of the head being far less, although the exact amount can not be determined on account of the imperfect preservation of the middle and anterior portions of the glabella.

Surface, wherever preserved, distinctly pustulose.

Probable length of glabella, 14 mm.; breadth of the same, 19 mm.; height of the middle part of the occipital margin above its lateral extremities, 5 mm.; length of the lateral spines, 2.5 mm.; length of the postero-lateral spine, 7 mm. Height of the preserved part of the glabella above the margins of the head, 10–11 mm. Probable width of the entire head, 25 mm.

Locality and position. John Brown's Quarry, New Carlisle, Ohio, from the collection of the Ohio State University, kindly loaned by Prof. Edward Orton.

GENUS BATHYURUS, Billings.

II. BATHYURUS —— ——.

(*Plate XIV, Fig.* 5.)

Only a single fragment known, whose relation to this genus is rather conjectural.

Glabella conical, convex, distinctly defined anteriorly and laterally by a continuous quite deep furrow. Posteriorly a small oval, almost triangular tubercle is inserted between the occipital furrow and both of the postero-lateral extremities of the glabella; owing to these tubercles the outline of this portion of the head (the regions of the glabella) seems to broaden at their insertion and then to contract suddenly be-

hind them, meeting the occipital furrow at a considerable angle, within a line directly behind the postero-lateral extremities of the glabella proper. Dorsal furrow well defined, running behind the tubercles, forward to a point almost even with the anterior margin of the tubercle, then back again on the other side. Posterior margin of the regions of the glabella an almost straight line running just behind the posterior ends of the tubercles. Glabella proper indistinctly marked by faint grooves. One of these grooves cuts off from the postero-lateral extremities of the glabella, parts somewhat larger than the tubercles. A second groove (also directed obliquely forward, but at a smaller angle) is placed a little anterior to the middle of the glabella, and extends about one third of the distance across the glabella. Anterior to this are one or two additional grooves, more faint, and also directed obliquely forwards, at a slightly greater angle than the last. All of these grooves are visible only after careful examination.

The anterior margin of the head curves quite rapidly downwards, so that the general shape of the preserved parts of the head is even more convex anteriorly than laterally or posteriorly. Anterior margin separated from the rim by a sort of furrow, from which the narrow rim rises up at an angle of about 45 degrees. The rim lies in a broad curve, passing within a short distance of the groove defining the anterior portion of the glabella. The facial sutures begin at the rim on a line about even with the lateral margins of the tubercles, thence extending inwards with a slow curvature, approaching within a very short distance of glabella behind its middle, and then apparently extending outwards where the outline is lost from want of preservation of the fossil. The antero-lateral extremities of the margin are therefore almost rectangularly pointed.

Length of the glabella to the occipital furrow, 7 mm.; to the posterior margin, 8.2 mm.; from the posterior margin to the anterior rim, 10 mm. Breadth of the glabella at its middle, 6.2 mm.; at its posterior, 6.9 mm.; across the tubercles, 7.4 mm. Distance between the tubercles, 4 mm. Length of the anterior rim, about 7.8 mm.

Locality and position. Soldiers' Home Quarry, Clinton Group.

GENUS ILLÆNUS, Dalman.

III. ILLÆNUS DAYTONENSIS, *Hall and Whitfield.*

(*Plate XIV, Figs.* 4 *a, b; Fig.* 6; *Figs.* 7 *a, b, c.*)

Species described by Hall and Whitfield in Ohio Pal. Vol. II.

Fixed cheeks one-third as wide as the space between the dorsal furrows. Palpebral lobes not coming to as sharp a point as figured in the Ohio report, but apparently a little rounded at their ends. Postero-lateral limb of the glabella beginning with a small groove at the base of the dorsal furrow which gradually widens towards the suture line, where it extends from the palpebral lobe to the occipital margin. Posterior portion of the facial suture curves outward from the posterior of the palpebral lobe, cutting the occipital margin at, or slightly beyond a line vertical to it and drawn from the most prominent part of the palpebral lobe.

Anterior margin of the pygidium trilobate, the middle lobe projecting a little, the lateral ones slightly curved at first, almost straight, then bending strongly and obliquely backwards, more or less angular at this point; then curving around and after a slightly angular deflection coalescing with the lateral margin. Antero-lateral angles never so prominent as those figured in the Ohio Report, although somewhat approaching them in this feature.

Movable cheeks small, greatest elevation at the upper posterior margin, making a large sweeping curve as it passes from the posterior to the lower or lateral margin. The facial suture before the eye making an angle of 30 degrees with the lateral line. Since this suture line agrees with the corresponding part of the glabella, these separated cheeks have been referred here.

Glabellae, pygidia, and movable cheeks so far not found in connection. The association of the glabellae and pygidia may be considered certain from their relative frequency and similarity to nearly related species. The cheeks are more conjectural in their relationship, although tolerably certain from their form.

Smallest glabella, 9x11 mm. One of larger size, 40 mm broad at the palpebral lobes, 30 mm. long, 13 mm. high. Smallest pygidium, 4x5 mm. One of larger size, 34 mm. broad, 25 mm. long, 5 mm. high. Movable cheeks 7-8 mm. broad, 12 mm. long to the point where it disappears beneath the glabella. Eyes two mm. long in the small specimens found.

Locality and position. Soldiers' Home, Fair Haven, Preble county, Clinton Group, abundant.

IV. Illænus Madisonianus, *Whitfield.*

(*Plate XIV, Figs.* 1 *a, b; Figs.* 2 *a, b.*)

Pygidium paraboloid in outline, its anterior margin arching strongly forward in the middle, and its surface very convex. Lateral margin spreading, forming a broad shallow furrow around the sides and behind, just within the edge; anteriorly this furrow extends up the articulating slope or facett of the pygidium, leaving it at about half the distance from the top of the anterior margin. Anterior margin with a rounded ungrooved edge, its corners just without the lateral furrows deflected downwards and forwards. A narrow faint ridge running from the posterior edge, half way up the pygidium. Entire surface minutely punctate with small pits .1 mm. in diameter, these interspersed with others of still smaller size.

Length, 30 mm.; breadth, 38 mm.; height 14 mm.; extension of the anterior margin forward beyond a line connecting the antero-lateral extremities, 9 mm. At the middle of this line is found the greatest elevation of the pygidium.

Our specimen is less abrupt at the sides than the one figured by Whitfield and has a smaller elevation along its posterior portion, but the general characters agree very closely with the published description and figures of the original. The recurved spreading margin seems to distinguish it from *I. insignis* of Hall, the nearest related species.

Locality and position. Clinton Group, Huffman's Quarry.

Another individual from the Soldiers' Home Quarries is proportionately broader, more depressed, less extended anteriorly, and provided at the anterior margin with a groove. Otherwise it agrees closely with the above form.

V. Illænus ambiguus, *sp. n.*

(*Plate XIV, Figs.* 9 *a, b: Figs.* 10 *a, b, c; Fig.* 11.)

Glabella regularly arcuate from front to base; anterior border with the margin neatly rounded. Occipital furrow well defined, with a faint upward extension at its middle, barely visible, within which is a minute granule, which can readily be recognized on wetting the specimens. Extending towards the anterior margin from this part is an indistinct ridge, which can be recognized only with difficulty, except in an occasional specimen where it may become moderately distinct.

This corresponds to a much more evident (although narrow) ridge, on the pygidium associated with these glabellae. In the occipital furrow at about two-thirds the distance of its postero-lateral margin from the granule is a deep, very distinct pit becoming shallow in older specimens.

From this the dorsal furrow extends inwards as a deep groove forming a broad, oval depression opposite the palpebral lobe, thence it extends as a shallow groove, rapidly becoming indistinct, in an outward direction, terminating in a small pit, which can be easily recognized even in specimens which do not show the connecting part of the groove distinctly, as is usually the case. This pit contains a minute granule. It is situated at two-thirds the distance of the anterior margin from the palpebral lobe. Half way between this pit and the anterior margin is a minute granule, easily visible on wetting the specimen. Widest part of the glabella lies between the palpebral lobes, anterior to which it becomes narrower and again widens reaching almost the same width at a point just behind the junction of the facial suture with the anterior margin. Facial suture extending from the edge with a distinct outward curvature to a point opposite the terminal pit of the dorsal furrow where it makes a rapid curve inwards to its junction with the anterior margin, in which the facial suture seems to terminate without any break. Palpebral lobe rounded. Facial suture behind the palpebral lobe starts from the posterior incurved extremity of each eye, and curves rapidly outward, cutting the margin directly behind or a slight distance beyond a vertical line drawn from the most prominent part of the palpebral lobe to the occipital line. Greatest elevation of the glabella lies between the palpebral lobes.

Pygidium semi-circular in outline, becoming slightly paraboloid in larger specimens, with a narrow more or less strongly marked ridge. Ridge extending from the posterior margin upwards, usually not reaching the middle of the pygidium. It can always be recognized. Along the anterior margin lies a groove, which is somewhat straight along its middle third, a small inward curvature near the middle, being very slight, aids in this appearance. At either side the groove makes a short curve inwards, and then outwards, approaching the lateral margin, along which it extends for a short distance, rapidly becoming obsolete. The deflection of the antero-lateral border causes a raised, ridge-like eminence to remain between it and the antero-lateral portion of the marginal groove. Pygidium flattish along the upper anterior

surface; greatest elevation at one-third the distance from the posterior margin, from this point rapidly curving downwards to the posterior margin, less rapidly towards the side and anterior portion.

Movable cheeks broadest at the posterior end of the eyes, with a deep-rounded furrow around the base of the eye. In large specimens rounded above. The facial suture inclining at an angle of sixty degrees to the lateral margin in front and meeting it at an angle behind which might be called a right angle, with the vertex rounded. It has also quite a sharp edge along its posterior margin, where the cheek makes a curve beneath the glabella. Since the angle made by the facial suture anterior to the eye corresponds to that made by the suture anterior to the palpebral lobe in the glabella, the cheeks are associated with this species. Eyes placed almost parallel with the upper part of the movable cheeks, lunate, forming about one-third of a circle. Lenses minute, about 17 to a millimeter. In the specimen examined they were only fairly preserved but there were about 20 in the vertical rows and perhaps 125 in the horizontal ones.

Glabellae, pygidia and movable cheeks so far not found in connection. The association of the glabellae and pygidia may be considered tolerably certain from the great abundance of both as compared with those of *I. Daytonensis*, the only other species found here in abundance. The association of the movable cheeks with these forms is more conjectural.

Smallest glabella, 8x10 mm. Ordinary sized specimen, 38 mm. broad across the palpebral lobes; 35 mm. across the anterior pits of the dorsal furrows. Direct length of glabella from anterior to occipital margins, 23 mm.; from anterior margin to a line drawn from the occipital margin perpendicular to the plane of the lateral margin, 20 mm.; height, 14 mm. A few large forms have been found which I refer to this species. The largest and most perfect of these is in the collection of Ira Crawford. It measures 60 mm. across the palpebral lobes and 54 mm. in a direct line from the anterior to the occipital margin; height, 30 mm. Smallest pygidium 10x13 mm. Ordinary sized specimen, 29 mm. broad at the antero-lateral margins; 24 mm. from posterior to articulating margin; 8 mm. high. A single large pygidium referred here measures 52 mm. in width; 44 mm. in length; 16 mm. in height. Movable cheeks, large specimen, length, 31 mm.; breadth, 20 mm.; length of eye, 7 mm. Smaller specimens proportionate.

Usually in the form of casts, surface where preserved apparently striated concentrically, at least around the edges, and dotted with small, shallow pits.

Locality and position. Soldiers' Home and vicinity. Clinton Group. Abundant.

GENUS CALYMENE, Brongniart.

VI. CALYMENE ———.

(Plate XIII, Fig. 24.)

Portions only of the head found, as fragments; the figure partly a restoration effected by a comparison of numerous fragmentary specimens. A fuller description will be given in the next paper if better material be found.

Glabella more prominent than the cheeks, very strongly defined from them by a deep, flat, longitudinal depression, which extends from the tip of the middle lateral lobe forward, forming an almost straight line along the line of separation from the fixed cheek, and terminating near the anterior end of the glabella, the side towards the fixed cheek being somewhat pointed. A similar depression behind the middle lateral lobes separates the posterior lobes from the surrounding portions of the head, its curvature being about that of the margins of the posterior lobes. The anterior border of the head is *broad* and *flat*, and directed upwards, with no arching along the middle as in specimens of *Calymene Niagarensis.* The anterior rim of this border has a slow curvature, appearing more like a straight line in some specimens than any species I am acquainted with. In other specimens, however, there is a somewhat greater curvature to the anterior rim. The facial sutures beginning with a slight outward curve for a small distance become almost parallel to each other as far as the eyes (which I now believe are incorrectly indicated in the drawing). Occipital furrow and as much of the fixed cheeks as is preserved, seem similar to the corresponding regions of *C. Niagarensis.*

Measurements are not given, on account of the unsatisfactory condition of the specimens. The figure is based upon a specimen preserving the glabella, anterior border and portions of the fixed cheeks, (all of the cheek anterior to the middle lateral lobe on one side of the glabella.) The rest of the figure is the result of comparison. The description is given mainly to note the existence of a form which has

a *broad, flat, anterior border, with no arching in the middle, and with almost parallel facial sutures anterior to the eyes.* It will be made the object of future study.

Locality and position. Soldiers' Home Quarries, Clinton Group; not rare.

VII. Calymene Blumenbachii? Brongniart.

(*Plate XIII, Fig.* 25.)

General form broadly oblong.

Cephalic shield short and broad, the width twice as great as the length. Glabella quite prominent, projecting above the rest of the head; its general form, including the lateral lobes, conical, widest across the posterior lobes, the width at this point slightly more than its length excluding the occipital ring, and only four-fifths its length including the same. Glabella supplied with three more or less distinct lobes laterally, the posterior lobes large and prominent, equal in elevation to the glabella between them, although they seem to rise above it, on account of its downward slope posteriorly; the middle pair of lobes about half their size, the anterior pair small, indistinct. The middle and posterior pairs of lobes separated from themselves by deep grooves, from the glabella by grooves becoming shallow at the point of union of the lobes with the glabella, and from the cheeks by grooves of less depth, becoming shallow at the middle lobe; a slight groove anterior to the occipital furrow connects the deepened grooves extending along the anterior edge of the posterior lobes. The anterior part of the glabella quite regularly rounded. The curvature of the glabella towards each side much larger than along its length, the latter being almost regular along the middle of the glabella. Occipital furrow very distinct, arched forward along the centre, curving forward also at each side, around the posterior lobe; the posterior edge following about the direction of the occipital furrow. Anterior border of the head forming a broad and even curve about the head, the border *fairly broad, flat, turned a little upward, not arched in the middle*, somewhat like the species last described. Facial suture beginning with a slight outward curvature at its very origin, then a gradual inward curvature as far as the eye, then it curves around the eye, and posteriorly to it takes an almost lateral direction as far as the edge of the elevated regions of the head, along this edge it is directed to the

postero-lateral edge of the head. Palpebral lobe fairly prominent. Fixed cheeks provided with a very deep and broad furrow close to the posterior margin, following its direction. Movable cheeks with thick, rounded lateral margins, defined by a distinct, rounded, lateral furrow, above which the remaining portion of the cheek is decidedly elevated. The curvature of the anterior and lateral margins of the head is quite regular, with the exception of a slight more or less evident inward curvature just behind the origin of the facial suture.

Thorax not entirely preserved, the number of articulations not known. Central lobe of the articulations elevated above the lateral lobes, more arched than the lateral lobes, separated from them by a distinct longitudinal furrow. Segment of the middle lobe arched forward along the middle, also bent a little forward at the sides, where they show a low, nodal thickening. The grooves separating the segments deeper at the sides, leaving a sort of axis along the centre of the middle lobe. The articulations of the lateral lobes extend laterally for a short distance and then are deflected posteriorly to their ends. A longitudinal furrow extends along each articulation dividing off its anterior part by a deeper and broader furrow than that which separates the articulations from each other.

Width of the head, about 64 mm.; length, 30 mm. Width of the glabella across the posterior lobes, 21 mm.; length, not including the neck segment, 19 mm.; including the same, 24 mm. Distance between the points of union of the facial sutures and the lateral margins, 19 mm.; forward extension of the anterior border, 6.5 mm. Probable length of the entire specimen, 105 mm.

Locality and position. Allen's Quarry, Clinton Group, in the upper shaly course. The specimen crumbled partially away on removal.

Fragments of glabellae and surrounding portions belonging to this species are found at the Soldiers' Home Quarries, also near the top of the group, in the upper shaly courses. Associated with these are pygidia, which seem to belong to this species, the connection is, however, rather conjectural than otherwise.

Pygidium wider than long, the posterior edge making a very broad curve, almost straight along the middle. The anterior and lateral margins as far as preserved having an almost semi-circular outline. Middle lobe rapidly tapering posteriorly, segments about eight, the tip

of the lobe (for an extent corresponding to about two segments) not divided, rounded posteriorly, the segments nearest the thorax similar to the segments there found. The more posterior segments have their ends curved decidedly backward, so as to follow the general semi-circular arrangement of the articulations of the lateral lobes. Lateral lobes divided from the mesial lobe by a distinct, quite deep furrow, broadening posteriorly. Articulations about six. The anterior articulations together with the segments of the mesial lobe forming a semi-circular curve. The posterior articulations become less curved and take a more decidedly backward direction. The last pair of articulations in this way become almost parallel to one another and together with the posterior edge of the pygidium form a sort of box into which the unsegmented portion of the mesial lobe enters from above. The articulations of the lateral lobes are furrowed above along the middle, the furrows extending almost to the edge of the pygidium.

Surface of the pygidia, and the head and thorax described above, finely granulated.

Width of pygidium, 37 mm.; length, 25 mm.; width of the anterior end of the mesial lobe, 15 mm.; width at the beginning of the unsegmented posterior portion, 6 mm.

Locality and position. Allen's and Soldiers' Home Quarries, in the upper, shaly courses of the Clinton Group.

GENUS LICHAS, Dalman.

VIII. LICHAS BREVICEPS, *Hall.*

(*Plate XIII, Figs.* 26 *a, b, c, d.*)

Glabella (Fig. 26 b) of one specimen convex. The middle lobe rounded in front, on each side suddenly and deeply incurved by the introduction of two lateral lobes, the sides almost parallel for a short distance posteriorly, then curving for a short distance outwards so as to meet the occipital furrow; at the point where the last curvature begins the posterior part of the lobe is 2.5 mm. broad, along the occipital furrow, 5 mm.; the width of the lobe is exactly equal to its length. Lateral lobes sub-reniform, almost twice as long as wide, separated from the middle lobe by sharp grooves evenly curved except at the posterior end where the expansion of the posterior end of the middle lobe causes a slight irregularity of curvature; anteriorly the lateral

edges of the lateral lobes continue the curvature of the anterior edge of the middle lobe, then they make a slow broad inward curvature, the posterior edge of the lobes being bounded by a groove continuing that part of the occipital furrow extending beneath the middle lobe. Within the inward curve of each reniform lateral lobe lies another lobe which I shall here call the *postero-lateral* lobe. Postero-lateral lobe separated from the lateral lobe by a sharp groove, its posterior edge is defined by a continuation of the groove behind the lateral lobes, directed a little backwards, however; from the palpebral lobe it is separated by a distinct groove curved outward and then inward, the curve disposed to be angular at its middle. Palpebral lobe preserved only anteriorly, its outer lateral edge elevated above the inner, the whole palpebral lobe having evidently been elevated along its outer surface. Postero-lateral tubercles transversely oblong lanceolate, inserted beneath the lateral and postero-lateral lobes, posteriorly they are bounded by the occipital furrow which bends somewhat backwards from the postero-lateral edges of the middle lobe so as to define the edges of the tubercles. The posterior edge of the neck segment has a very slight forward curvature towards the middle. Anterior margin of the head narrow. Surface irregularly pustulose.

Width across the widest part of the middle lobes, 8.6 mm.; across the lateral lobes, 9.5 mm.; across the postero-lateral lobes, 11.5 mm.; across the postero-lateral tubercles, 8 mm. Distance between the tubercles, 4 mm. Length of the middle lobe, 8.6; including the neck segment, 10 mm. Stolz's quarry.

Another glabella shows only middle, lateral, postero-lateral and palpebral lobes, with only a little of the neck segment nearest to the occipital lobe. It agrees with the foregoing specimen in all particulars as far as can be seen, except in the existence of a low groove across the posterior end of the middle lobe where it begins to take an outward curvature. This groove is parallel with the occipital furrow just behind it. The palpebral lobe is also better preserved and shows a regularly rounded outer edge, the surface elevated along the outer margin. Surface of the glabella irregularly pustulose. John Brown's Quarry, New Carlisle. Specimen almost twice the size of the last.

A third specimen (Fig. 26 a) differs widely from the two above in some things. It is far more convex, and proportionately wider. The grooves about the glabella and the lobes into which it is divided also differ materially, more so than the figure intimates, but a fuller

description will be deferred until more and better material is at hand for accurate description. Stolz's Quarry.

Pygidium, general form semi-elliptical, quite straight along the anterior border, rapidly curved at its antero-lateral extremities. Axial lobe broad and strong, very prominent in the anterior part, rapidly narrowing and becoming low in the middle, and again widening posteriorly, but not equaling its anterior width; its width at the anterior margin one third the width of the pygidium; one distinct anterior annulation, with apparently a faint indication of a second. Lateral lobe with three segments on each side, and each marked by a distinct, longitudinal furrow along its middle. At their posterior side the two anterior lobes project a little beyond the margin of the pygidium, the rest of the outline being regularly rounded. The two anterior segments directed backwards, the posterior segment bent first a little outward then backward, filling up the outline along the contracted middle of the axial lobe. Under the exterior crust of the pygidium are a series of lamellose striations following the posterior and lateral outline of the pygidium and reaching about one-third the length of the pygidium towards the centre. Surface pustulose as in the first described glabella; having been found in the same piece of rock, it is supposed to be the pygidium of this species.

Length of the pygidium, 17 mm.; width, 24 mm. Width of the axial lobe anteriorly, 8 mm.; along the contracted portion, 4 mm.; at its greatest expansion posteriorly, about 6.5 mm. Stolz's Quarry. Other pygidia presenting the same features found here.

Locality and position. Stolz's Quarry, both glabellae and pygidia; John Brown's Quarry, New Carlisle, a glabella, kindly loaned from the collection of the Ohio State University, by Prof. Edward Orton. Clinton Group.

GENUS ARIONELLUS, Barrande.

IX. ARIONELLUS ———.

(Plate XIV, Fig. 3.)

It would be difficult to tell why the species here described should be placed under the generic name above mentioned, differing, as it does,

in almost every important characteristic; nevertheless in some respects it seemed to me to be as closely related to this genus as to any other, and until further study may lead me to a more definite result, I concluded to leave it here.

Glabella very convex towards the anterior margin, which is rounded; less convex laterally; separated from the cheeks by almost straight furrows, converging behind to about four sevenths the width of the glabella at its broadest part. At about half the length of the glabella, on each side, are two grooves. The middle pair are broadly crescent shaped, the points directed downward, distant from one another about two fifths the width of the glabella at that point, their general direction being lateral; they do not quite reach the lateral margins, however. From the ends of these, a second pair of crescent shaped grooves extend forward and laterally, reaching the furrows which define the lateral sides of the glabella. The second pair does not merge into the first at their adjacent extremities. Behind these grooves a third pair, distant from each other about two fifths the width of the glabella at that point, cut off about one third of the lower half of the glabella; they are directed obliquely backwards, at an angle of about sixty degrees with a line extending lengthwise along the glabella; their curvature is first a little backwards, then more laterally, then a little backwards again, making a gracefully undulated curve which does not quite reach the lateral margin of the glabella: a fourth pair of grooves, cutting off the last third of the lower half of the glabella, is similar to this pair. The occipital furrow is scarcely preserved but seems to have been regularly curved, the middle of the curve being directed forward.

Fixed cheeks, at least as far as preserved, highest anteriorly, where their convexity is also the greatest. The front margin beginning just behind the first pair of grooves on the glabella is curved postero-laterally, then backward and slightly inward, lastly, again postero-laterally to the postero-lateral corner of the cheek. The occipital furrow extends laterally along the posterior border of the cheek near the margin as a deep furrow. Surface smooth.

Length of the glabella, 4.1 mm.; width at the broadest part, 4.1 mm.; at the narrowed posterior extremity, 2.4 mm.; width of that part of the head included between the postero-lateral corners of the fixed cheeks, 5.4 mm.; length of the fixed cheeks, 2.2 mm.

Locality and position. Soldiers' Home Quarry, Clinton Group.

GENUS DALMANITES, Emmrich.

X. DALMANITES WERTHNERI, *sp. n.*

General form of the body elongate-ovate, greatest breadth across the posterior part of the cephalic shield.

Head convex, semi-circular, breadth about five-thirds as great as the length; border extended in front into a semi-circular process, which varies from forms in which it is scarcely evident, to those in which it equals about two-fifths of the breadth of the anterior border in its projection beyond the curve of the border itself, never as distinct as in *D. vigilans*; base about one-fourth as broad as the greatest width of the glabella, or even less; lateral borders broad, separated from the cheeks by a distinct groove, produced posteriorly into rather long and slender curving spines, which continue the curvature of the lateral borders of the glabella.

Glabella large, depressed convex, widening in front to almost twice its width at the posterior margin, divided into lobes by three pairs of transverse furrows in addition to the occipital furrow, which is distinct and continuous. All three furrows distinct at the sides, not extending entirely across the glabella except in some specimens as a faint depression. Anterior furrows deeper, situated a little anterior to the eyes, giving to the frontal lobe a transversely elliptical outline; occipital ring narrow, without a spine as far as known. Eyes very prominent, short reniform, containing obout thirty-five vertical ranges of lenses, the middle ranges having six to seven each; palpebral lobe depressed, giving great prominence to the rim of the eyes. Cheeks small, anteriorly quite prominent, posteriorly marked by a deep, bordering groove, the continuation of the occipital furrow, margin flat.

Thorax with the axial lobe convex, widest at the sixth segment, its greatest width about two-thirds that of the lateral lobe, or a little larger. The articulations curve forward a little near the middle and at their junction with the lateral lobes; articulations of the lateral lobes traversed by a deep longitudinal furrow extending from the junction of the anterior margin with the axil lobe, backwards along the anterior margin of the articulation, at about one third the width of the articulation, leaving it towards the extremities. From the imperfect preservation, the exact method of leaving can not be determined.

Pygidium broadly ovate-triangular, the lateral borders flattened, axial lobe regularly tapering posteriorly, marked by about thirteen annulations, which gradually decrease in size posteriorly and end in a spinose elevation. This spinose elevation is often accompanied by an upward deflection of the border posteriorly and terminates in a minute point at the end of the border. Although the pygidia are very abundant no spinose projection beyond the border has so far been observed. Antero-lateral margin of pygidium rounded, lateral articulations about ten in number, all, except the last three, grooved like the articulations of the thorax, becoming indistinct on the margin of the pygidium.

Head irregularly pustulate (pustules small) except the anterior and lateral borders of the head, which are minutely granular. Remainder of the body irregularly pustulate, pustules small, a single pustule slightly larger in size on each segment of the axial lobe of the pygidium, inconspicuous.

Small specimen, length of body, about 25 mm.; breadth, 16 mm.; length of head, 9 mm., breadth, 15 mm. Head (of usual proportions), length, 12 mm.; breadth, 20 mm.; convexity, 4 mm.; breadth of anterior lobe of the glabella, 10 mm.; of the posterior lobe, 5½ mm. Pygidium, length, 17 mm.; breadth, 22 mm.; breadth of axial lobe anteriorly, 6 mm.

The furrows across the axial lobe are much more distinct at the sides than at the middle, especially in the pygidium. The anterior lobe of the glabella has near its posterior extremity a distinct, elongated pit, which seems to be characteristic of this species.

Locality and position. Soldiers' Home Quarries. Clinton Group. (Named in honor of Mr. W. B. Werthner, who was present at the first discovery of this species. Abundant in some localities.)

In connection with the minute forms described above from the Beavertown marl, the following will be of interest:

GENUS ORTHOCERAS, Breynius.

ORTHOCERAS INCEPTUM, *sp. n.*

(*Plate XIII, Figs.* 1 *a, b, c.*)

Shell very small and slender, enlarging from below upwards gradually, in one specimen from 4 to 5 mm. in a length of 10 mm., in others more slowly. Transverse section almost circular, one diameter slight-

ly longer, or more elliptical; length of the outer chamber not determined. Septa concave—six chambers occupying a length of 10 mm. in the specimen above mentioned. Siphuncle eccentric, nearer to the centre than to the margin, narrow at the septa, expanding within the chambers.

Surface apparently not preserved, specimens in the form of casts. There are indications of longitudinal striæ, preserved with various degrees of distinctness, in some worn specimens looking like rows of small pits. Along one side of the shell, nearest the position of the siphuncle is a narrow, raised, longitudinal line, laterally defined by grooves which more or less coalesce anteriorly towards the annular rings (septa), and thus produce interruptions along the line. The distinctness of this longitudinal line is extremely variable, or perhaps is due to the removal of some of the surface matter, because some of the best preserved specimens are smooth, whereas those which are worn are apt to present these features. (Cf. *O. Duseri, Hall and Whitfield.*)

Locality and position. Beavertown marl, Clinton Group. A specimen in the Ohio State collection, from Wilmington, Ohio, I refer to this species.

Explanation of Plates.

Plate XIII.

Fig. 1. *Orthoceras inceptum, n. sp.:* a, lateral views; b, views showing the position of the siphuncle; c, vertical section through the siphuncle.

Fig. 2. *Meristella umbonata, Billings* (sp.); a, lateral view; b, dorsal valve.

Fig. 3. *Platyostoma Niagarense, Hall:* a, b, specimens referred to the Ohio forms considered identical with the Indiana species, having the aspect of *Holopea.*

Fig. 4. *Eichwaldia reticulata, Hall:* a, dorsal valve; b, ventral valve.

Fig. 5. *Leptæna prolongata, n. sp.:* a, ventral valve; b, lateral view, outline.

Fig. 6. *Zygospira modesta, Say* (sp.); dorsal valve.

Fig. 7. *Orthis biforata,* var. *lynx* (*Von Buch*), forma *reversata;* ventral valve.

Fig. 8. *Orthis biforata,* var. *lynx* (*Von Buch*), forma *Daytonensis;* ventral valve.

Fig. 9. *Atrypa nodostriata, Hall;* ventral valve.

Fig. 10. *Orthis hybrida, Sowerby;* a, dorsal valve; b, lateral view, drawn for the outline only.

Fig. 11. *Orthis elegantula, Dalman:* a, dorsal view; b, lateral view, drawn for the outline only.

Fig. 12. *Orthis flabella, Sowerby:* a, ventral valve; b, dorsal valve.

Fig. 13. *Orthis Daytonensis, n. sp.:* a, dorsal valve; b, lateral view, drawn for

outline only ; c, a few of the radiating striæ; d, occasional appearance of the surface characters.

Fig. 14. *Pterinea brisa, Hall:* a, b, views of different left valves referred to this species ; b, taken from a cast.

Fig. 15. *Orthis fausta, n. sp :* a, dorsal valve ; b, ventral valve ; c, lateral view ; d, a few of the striæ.

Fig. 16. *Orthis fausta, n. sp.:* a, dorsal valve ; b, some of the striæ of the form *acuto-plicata.*

Fig. 17. *Orthis elegantula, var. parva, n var.:* a, ventral valve; b, lateral view of the same.

Fig. 18. *Bucania exigua, n. sp.;* a, view from above ; b, lateral view, the expansion of the aperture not well brought out ; c, lateral view of another specimen ; d, another view of the same.

Fig. 19. *Bellerophon fiscello-striatus, n. sp ;* a, lateral view ; b, c, d, views of the same; e, a part of the carina, with a few of the nearest striæ.

Fig. 20. *Orthis Daytonensis, n. sp.;* a, ventral view; b, interior view of the same.

Fig 21. *Orthis Daytonensis, n. sp ;* lateral view of a specimen presenting both valves.

Fig. 22. *Platyostoma Niagarense, Hall;* a, lateral view ; b, view from above.

Fig. 23. *Acidaspis;* part of the head.

Fig. 24. *Calymene;* part of the head, partially restored.

Fig. 25. *Calymene Blumenbachii? Brongniart:* head with a few of the thoracic articulations attached.

Fig. 26. *Lichas breviceps, Hall:* a, glabella, not typical ; b, typical glabella of Ohio form ; c, surface of the latter, variously magnified ; d, pygidium ; e, glabella of a specimen from New Carlisle.

Plate XIV.

Fig. 1. *Illænus Madisonianus, Whitfield:* a, view of a pygidium from above; b, lateral view of the same.

Fig. 2. *Illænus;* a, view of pygidium similar in some respects to that of *I. Madisonianus ;* b, lateral view of the same.

Fig. 3. *Arionellus?;* view of the glabella and fixed cheeks.

Fig. 4. *Illænus Daytonensis, Hall and Whitfield:* a, view of a pygidium ; b, lateral view of the same.

Fig. 5. *Bathyurus;* view of a glabella, the curvature of the rim of the anterior border not represented.

Fig. 6. *Illænus Daytonensis, H. and W.:* movable cheek, view obliquely from below.

Fig. 7. *Illænus Daytonensis, H. and W.;* a, lateral view of a head, the associated movable cheek figured ; b, view of the glabella from above ; c, view of the same from behind.

Fig. 8. *Nucula minima, n. sp.:* a, view of the anterior regions ; b, lateral

view ; c, view of the regions posterior to the beaks ; all views magnified six diameters.

Fig. 9. *Illænus ambiguus, n. sp.;* a, view of a pygidium seen from above ; b, lateral view of the same.

Fig. 10. *Illænus ambiguus, n. sp.;* a, lateral view of a head, the associated movable cheek figured ; b, posterior view of the glabella ; c, view of the same from above.

Fig. 11. *Illænus ambiguus, n. sp.;* movable cheek of unusually large proportions.

Fig. 12. *Grammysia Caswelli, n. sp.;* a, lateral view of the shell, anterior definition too sharp ; b, view of the same from above.

Fig. 13. ——— *triplesianus, n. sp.;* a, view of one of the valves; b, lateral view of the same shell.

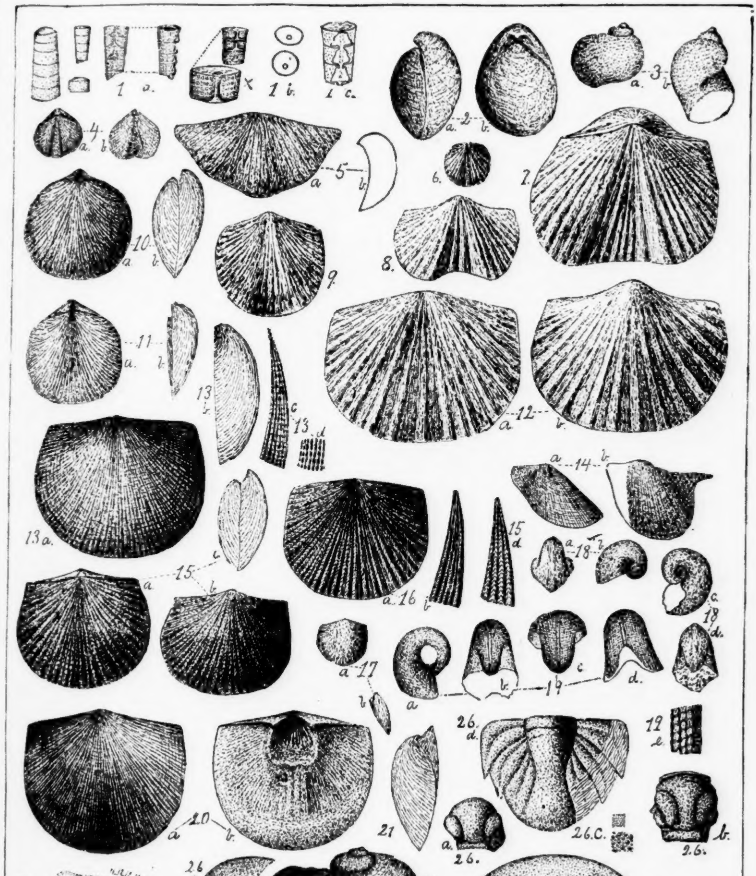
Fig. 14. ——— *triplesianus, n. sp.;* view of the other valve from a different specimen.

Fig. 15. *Strophostylus cyclostomus, Hall ;* lateral view of a specimen.

Fig. 16. *Trochonema nana, n. sp.;* two views, magnified to eight-thirds and four-thirds of the original size respectively.

Fig. 17. *Cyclora alta, n. sp.;* a, lateral views of specimens showing variations in the elevation of the spire ; b, view of the umbilicus of a specimen ; all views magnified two diameters.

Fig. 18. *Raphistoma affinis, n. sp ;* view from above, and also a lateral view, the umbilicus being directed upwards.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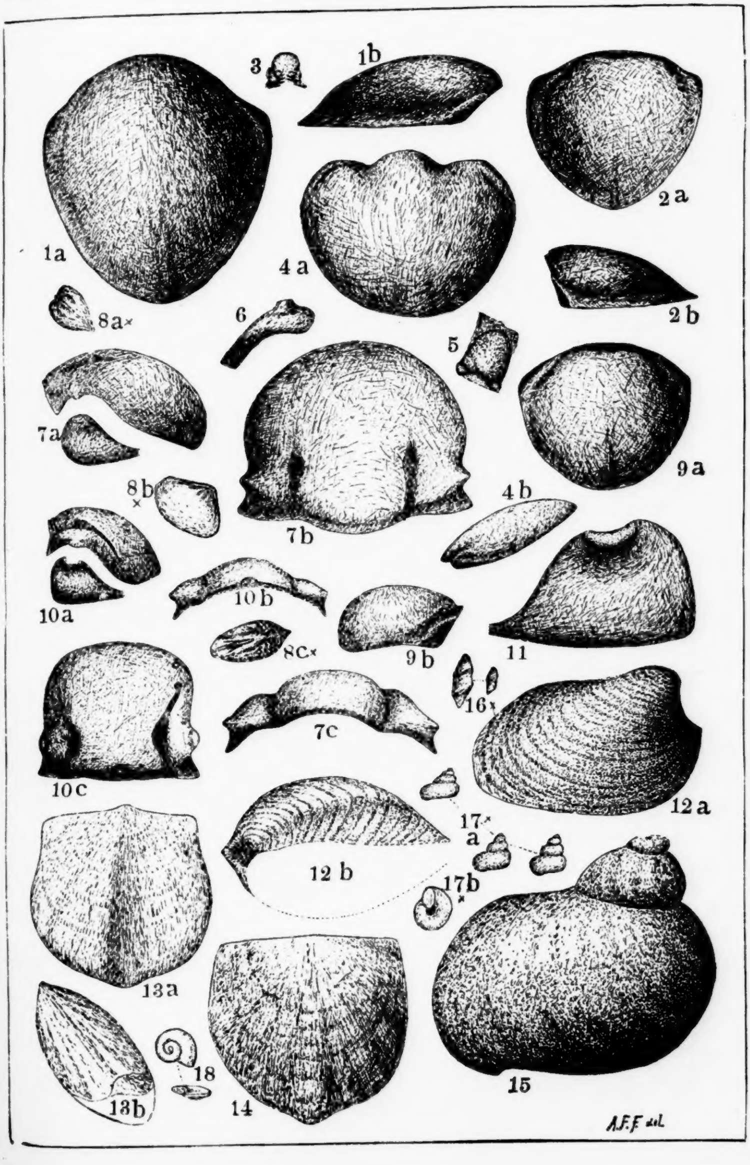
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VII.

A COMPEND OF LABORATORY MANIPULATION.

It is the design of the series of papers, of which this is the first, to present in concise form the methods of investigation which have proven themselves of greatest service in the laboratories of this country and Europe. No attempt at originality or completeness is made, but only such methods as have been experimentally proven useful will be admitted, while free use will be made of the modern text-books of Fol and Hussak.

It is acknowledged by all students that the proper method of research is the first essential to the prosecution of any line of investigation, and it is often stated that he who spends but half the time allotted to a given study in experimentally learning the best manipulation to employ, need not regret the time so spent.

The present paper deals with lithological appliances and methods and is supplemented by a condensed translation and adaptation of Hussak's "Einleitung." No apology is necessary for reducing the formulæ to the system in vogue in this country nor for giving prominence to the subject of lithology, in view of its rising importance and increasing recognition.

CHAPTER I.

Lithological Manipulation.

A. Rock Sections.

In no department of geology has there been so great an advance of late in this country as in the study of the intimate structure of rocks by means of thin sections. The science of lithology is rapidly evolving from a chaotic condition and assuming the similitude of a system. Although the pursuit of this study has been confined to a limited circle and it has scarcely appeared in our literature, much may be expected in the near future.

The impetus given years ago by *Zirkle*, in his "Microscopic Petrography," has slowly become apparent. Hawes, in his work upon New Hampshire lithology, contributed substantial material to the same science, while the more recent reports of the Wisconsin geological survey afford evidence that the work is going on. Several of the State geological surveys are now in the midst of investigations in this direction the results of which may be looked for with great interest. The United States surveys are not behind in cultivating the promising field.

Great as is the promise of research in this direction, we are equally interested to observe that the introduction of the new method of study of rocks is to a degree revolutionizing the study of geology. The same methods which have so greatly augmented the disciplinary value of biology by connecting histological and laboratory practice with its study, are introduced into the courses in geology and the student is taught to *see through*, as well as to look at, rocks and minerals.

The study of a rock or mineral involves, first, the investigation of the origin, age, and relations of the rock, which invoke respectively the sciences of geotechnical, historical, and stratigraphical geology; second, the study of the rock itself, which may be carried on by means of chemical and physical tests. Under the latter head come crystallography and physical mineralogy. The chemical examination involves the application of heat, as in blow-pipe analysis, or of chemical reagents in the wet way.

The physical examination of minerals may be conducted microscopically or macroscopically, depending upon the employment or non-employment of aids to ordinary vision. Ordinary physical mineralogy is occupied with such of the optical or other characters of minerals as can be made out with the unassisted eye.

In order to prepare a mineral or rock for microscopic examination it must, in most cases, be reduced to a transparent condition in order that it may be studied by transmitted light. The facts which can be obtained by the microscopic examination of opaque masses in reflected light, are few and unimportant.

A rock may be reduced to a powder and mounted in a transparent medium and many of its elements detected by microscopic examination of the angles and surfaces of the fragments. In this way particles too small for measurement by the ordinary goniometer may be determined. Such of the resulting particles as are transparent may

be optically examined, though there are many opportunities for error. It is recommended that rocks of a rather finely granular structure be examined in this way with reference also to the specific gravity. A fragment of suitable size is reduced to a powder, the fineness of which may vary with the size of the granular elements in the sample. The powder is then assorted under water by agitating repeatedly in a bottle and hastily pouring off the fluid, leaving the part first to settle and repeating the process as often as any separation is possible. Denser fluids (See Hussak Anleitung, p. 51,) may be used with advantage in some cases. By mounting different parts of the powder thus sorted separately or under separate covers upon a single glass slip, interesting qualitative and even approximate quantitative results may be obtained.

Comparatively few minerals or aggregates are sufficiently transparent to permit of optical examination by transmitted light. A few of these, as mica, gypsum, calcite, dolomite, etc., are adapted for study without other preparation in any way. In cases where the cleavage is irregular and does not permit the breaking out of tabular plates it becomes necessary to mount the irregular fragments in a highly refractive medium, such as balsam, between glass slips, and thus to eliminate as far as possible the dispersion and irregular refraction. Even then the results are often unsatisfactory. Sands and other fragmentary rocks may be examined by the following method, suggested by *Thoulet.*

The powder or sand is mixed with about ten times its volume of zinc oxide, then silicate of potassium is stirred in till the whole assumes the consistency of a stiff broth. This, while still soft, may be pressed into a mold, formed from a section of a glass tube glued to a slip. When set, the resulting cylinder is removed and fastened to a slip of thick glass and ground in the way described beyond for compact rocks.

When a rock or mineral is not transparent and does not admit of breaking into sections of suitable thinness with the hammer, it becomes necessary to cut or grind a section of sufficient transparency and then mount it between glass in Canada balsam. Before beginning this somewhat tedious process the student should provide himself with the following outfit: (1) A number of thick squares of plate glass about one half inch thick and two inches square, these being ground on the edges in order to avoid cutting the fingers; (2) several dozen slips of

thin perfect glass for mounting the sections, the size preferred being 45 by 25 mm. and is furnished by any dealer in microscopes; (3) a corresponding number of covers of thin glass, square in shape and large enough to extend nearly across the slip; (4) a jar of balsam nearly solid or of the consistency of honey and lumps of solid balsam, (the balsam thould be in a wide-mouthed bottle covered with a protecting shield or glass stopper, through which extends a dipping rod); (5) several grades of emery powder, it being convenient to have numbers 0, and 1, and emery flour, as well as a small quantity of emery slime. This last is not kept by ordinary dealers and is made by decanting off the finest impalpable powder during the grinding of other grades. It may be secured of Julien, of New York, or through Bausch & Lomb, of Rochester; (6) an alcohol or gas lamp; (7) a heating table or tripod with brass plate, for heating the slides; (8) a number of spring clothes pins, with the lips filed flat, to hold the cover glasses while the balsam drys; (9) a bottle of solution for cleansing the glasses, which is prepared from sulphuric acid and chromate of potash; (10) a contrivance of some sort for grinding or sectioning the rock. The simplest way is, after breaking as thin a fragment as possible from an unweathered sample, to grind one side of the fragment upon a smooth iron surface with coarse emery and water until a plane surface is secured as large as a quarter or larger. The surface is then ground with emery flour upon a large, smooth plate of glass, after which a polish is secured by long rubbing on a second plate with emery slime. The surface thus prepared is glued to one of the squares of plate glass with balsam. The best results are secured by using balsam which is quite hard but not yet brittle; it should yield to the nail with difficulty, but should not shiver into fragments. A small piece is placed on the cleaned surface of the square and set on the brass plate of the tripod over the flame of the lamp. The chip of rock is also heated at the same time. When the balsam has become thoroughly fluid, but before bubbles appear, the section is pressed firmly down upon the balsam and as much of it pressed out as possible. Care should be taken that no bubbles or impurities find their way between the section and the glass. A weight or spring may, in some cases be necessary to prevent the slightest elevation of one side of the chip from the glass square. The balsam will set very quickly and, if the heating has been slow enough, will have become tough—it should no longer yield to the nail. The older lithologists advise the use of soft balsam, which is heated until it ac-

quires the proper consistency before each mounting, in a spoon, but there are many objections besides the tedious process involved. When any number of slides are to be made there is economy in having balsam of the proper sort at hand and if some becomes brittle it may be melted with some which is yet too fluid. It is desirable also to perform the same part of the process with a number—say a dozen—samples at once, as it saves time and the chances of accident are fewer, provided care be taken to avoid loosing the identity of the specimens. After the chip has been glued to the glass square the former is ground carefully with coarse emory of various grades until the section shows signs of falling to pieces, it is then put upon the flour and slime plates in succession. Great care must be used to prevent the accidental mixture of coarse emery or gritty grains with the emery flour or slime, as one grain of coarse grit may suffice to destroy the section just when completed. When the section is judged thin enough, it is proved by cleaning the square and laying it over print which should be clearly seen through the section. The superfluous and soiled balsam is carefully cleaned away from the section and it is placed on the heating table on which are also laid the slip and cover glasses. When the balsam is fluid, a small fragment of somewhat more fluid balsam than that previously used is placed on the glass slip and the thin section is pushed off the plate glass square with a blunt needle, the cool needle adheres to the section and the latter is removed to the now perfectly fluid balsam on the glass slip. The warm cover glass is now quickly placed over the section which has been completely immersed in the medium. Care must be taken that a sufficient quantity of balsam is used to completely fill the space between the slip and the cover and also that no bubbles arise to obscure the field. If all has been successful the spring clips are applied and the slide is placed aside to dry without attempting to clean away the superfluous balsam. In a day or two this will be hard enough to be readily removed with a knife and the slide may be cleaned with a soft cloth wetted with alcohol, care being taken that the balsam under the cover is not attacked by the alcohol. The slide is then ready to label in any convenient way, the number of the corresponding hand sample being in every case attached to the slide.

The process above described is less tedious than might be supposed but can be materially shortened by the use of a lithological lathe provided with lead and iron horizontal laps. The accompanying wood

cut illustrates the form of lathe used for this purpose in our own laboratory. It was manufactured at the suggestion of this department and is not only more convenient and elegant, but less expensive than any other lathe at present in the market. It is constructed by W. F. and John Barnes Co., of Rockford, Ill.

In the study of the section thus prepared a microscope is used which is especially arranged for this purpose. The appearance of such an instrument is illustrated by the accompanying figure which

represents the polarizing microscope prepared by Bausch and Lomb, Rochester, N. Y., while figure 1. of plate XI gives a diagram of the optical parts, etc., of the Fuess-Rosenbusch stand in use in Germany.

The rotating stage is centered and graduated to record the angular position of the slide. The polarizer (rr) is placed below the stage and consists of a Nicols' prism set in a rotating cylinder. Above it is

a condensing lense for making the rays convergent. The light is polarized in one plane by the polarizer and (the condenser being removed) passes through the section placed over the aperture in the stage. The resulting image is now magnified by the microscope in the usual way. Above the ocular is placed the analyser, consisting of a Nicol's prism set in a revolving cylinder with a graduated limb. This prism serves to cut off all the rays polarized in one plane by the lower Nicol when its axis is at right angles to that prism. If, however, the interposed mineral section is double refractive and rotates the plane of polarization of the light, this fact is indicated by the fact that the field does not appear dark when the Nicols are at right angles, but at some other angle which enables us to ascertain the amount of rotation produced by the mineral in question. A quartz plate (*zz*) is inserted above the objective and serves to discover the slightest double refraction. An artificial calcite twin, known as the Calderon plate, is inserted in one of the oculars. If the mineral examined be not isotropous the two parts will be unequally dark, thus enabling us to distinguish the optical characters by a most sensitive test. A plate of calcite, set in a cork ring, is also used between the ocular and analyzer. The interference figure produced by the calcite now is superposed upon the mineral section and may or may not be distorted by the action of the latter, affording another criterion by which to determine the minerals.

B. *Micro-chemical Methods.*

In the application of chemistry beneath the microscope, tests of prime importance are derived from the solubility of the various parts of a section and the forms of crystals formed from an evaporated precipitate after a reaction is accomplished.

In order that the tests may be applied to but a single crystal of a section, it is necessary to perforate the cover glass with a minute opening, thus preventing the uncertainty otherwise unavoidable. An ordinary cover glass is coated with wax and a minute perforation is made with a needle, exposing the glass, which is then subjected to the action of hydrofluoric acid until the glass is eaten through by a perforation less than a millimeter in diameter. The section is then covered and the opening is brought directly above the crystal to be studied. The balsam is removed by alcohol and the surface of the crystal is thus exposed to the action. In the case of reagents giving off corrosive

fumes, the objective may be protected by a thin glass cover temporarily fastened to the end by glycerine.

As an example of the micro-chemical process we may mention the process of distinguishing apatite from nephelin. If the grain of apatite can be isolated it is dissolved in a concentric nitric acid solution of molybdate of ammonia. As the solution is slowly affected, a multitude of yellow octahedrons of $10\,Mo\,O_3 + PO_4\,(NH_4)_3$ appear about the edges. This detects the phosphoric acid. The lime may be demonstrated by dissolving the grain in nitric acid, to which is then added a drop of sulphuric acid producing small crystals of gypsum.

In case the questionable grain is in a section the acids may be applied with a glass rod and then removed by a pipette to a glass slip and there evaporated.

Nephelin fails to produce the reactions described but its solution in concentric hydrochloric acid affords, on evaporation, minute cubes of common salt which are very readily recognized.

Boricky has applied Fluo-silicic acid in the micro-chemical analysis of many minerals. The reagent must be chemically pure and about 13 per cent. strong. It cannot, of course, be preserved in glass vessels. Its availability arises from the fact that nearly all rock-forming minerals are attacked by it and the resulting compounds afford characteristic crystals.

A slide is covered with a thin protecting layer of balsam and upon this the particles to be examined are placed. When the substance is very slowly affected the best results are obtained by applying the reagent to the section itself. If the mineral is easily dissolved the various components appear approximately in their relative proportion in crystals of various form. In cases where the mineral is but slightly attacked, some of its components may first separate and thus make necessary a repetition of the process, or it may be faciliated by first dissolving these soluble substances in fluoric acid. The fluo-silicates crystallize most perfectly when evaporated and the watery solution permitted to again evaporate on a second slide.

1. *Fluo-silicate of postassium* crystallizes in the isometric system, usually in i–i in skeleton groups, also in 1, and I. The reaction is masked by presence of sodium, when apparently rhombic crystals ĭ–n . m–ĭ are formed.

2. *Fluo-silicates of sodium* give short hexagonal columns with O,

I, and i–2. Incomplete crystals are barrel-shaped, presence of calcium increases the size.

3. *Fluo-silicate of calcium* occurs in peculiar, long lanceolate crystals, often in rosettes. The angles and edges are not sharp. Monoclinic, easily soluble in water.

4. *Fluo-silicate of magnesium* appears in rhombohedrons the angles of which are truncated by oR, and in combinations of R . i–2 or R. i–2 . oR. It often appears in rhombohedrons deformed in one angle or in cruciate or pectinate forms.

Ferric and maganesic compounds can hardly be distinguished from magnesium fluo-silicate, and strontium compounds resemble fluo-silicate of calcium.

5. Lithia compounds appear in obtuse hexagonal pyramids, while fluo-silicate of barium occurs in excessively minute needles.

The fluorides of iron, magnesium, and maganese may be distinguished by subjecting them to the action of chlorine gas, which changes the color of the iron compound to citron yellow, of the manganese to reddish, while the fluoride of magnesia remains colorless.

Behrens gives the following method which, when carefully followed, is exceedingly delicate:—

The sample to be studied is isolated and pulverized and is placed in a covered platinum capsule not more than 1 cm. in diameter into which a few drops of fluoric acid, fluoride of ammonium, and concentrated hydrochloric acid have been placed, evaporate, and, if necessary, repeat the operation. The dried mass resulting is evaporated with sulphuric acid nearly to dryness, when gray fumes are formed. Add water and again evaporate so that for each milligram of the powder a centigram of fluid is produced. A drop of this fluid is now placed on the slide with a capillary pipette and, after protecting the objective, is examined for *calcium*. If calcium is presant, evaporation produces crystals of gypsum (I . i–i' . 1 .) On the margin of the drop characteristic swallow-tail twins may be found. .0005 mg. of lime can be detected in this way.

A drop of platinum chloride is now added and, if *potassium* was present, strongly refractive octahedrons or trillings or quadrillings appear.

Sodium is detected by cerium sulphate, a saturated solution of which is placed on the slide near the drop to be examined and connected with it by a capillary glass thread. In the drop of the reagent there

appear desmid-like aggregates of cerium sulphate and on the margin a brown cloudy zone of double salt of soda. Excess of sulphuric acid prevents the reaction.

Magnesium is detected by salt of phosphorus. The drop, before tested for possium or aluminum, is neutralized with ammonia and in a drop of water placed at a distance of about 1 cm. is placed a grain of salt of phosphorus and the two drops connected as before. The result is the production of double, forked crystalloids similar to those found in natural glasses or well developed hemimorphic twins of ammoniated magnesium phosphate.

Aluminum is detected by touching the drop with a platinum wire dipped in caesium chloride. Translucent octahedrons of caesium alumn are formed, or more rarely 1 . ī-ī. If the solution of the mineral is concentrated, dendritic forms simply are formed and water must be added.

Similar tests are proposed for the detection of other elements but the above are of most general application.

C. *Use of the Polarizing Microscope.*

Ordinary polarized light is produced by placing the analyzer above the eye-piece in such a position that its Nicol's prism stands at right angles to that in the polarizer below the stage. The field now appears totally dark, inasmuch as the only rays permitted to pass through the polarizer are extinguished by the analyzer.

All minerals are either simply or doubly refractive, and the former may be recognized as *amorphous* (like glass) or belonging to the *isometric* crystal system. Inasmuch as the elasticity of the ether in either case will be the same in any direction in such minerals, they do not interfere with the rays which pass through them, hence between crossed Nichols any section of such minerals remains constantly dark, even though the section be passed through a complete revolution by rotating the stage—in other words, the mineral is *isotropous*. Double refractive minerals, in sections taken in some directions, become colored in certain positions between crossed Nicols. Such sections become perfectly dark twice in one complete revolution. These colors are due to interference of the rays brought about by the double refraction.

Optical uniaxial crystals are those falling in either the tetragonal or hexagonal systems. In such crystals there is but one direction in which there is no double refraction, *i. e.* that parallel to the vertical axis *c*, which, in this case, corresponds to the optical axis. The elasticity of the ether contained in the crystal is different in directions parallel and at right angles to the main axis. $\mathfrak{a}$= the axis of the greatest elacticity and $\mathfrak{c}$= the axis of least elasticity. ω= exponent of refraction in the ordinary ray (that is, the one passing parallel to the optical axis and vibrating at right angles to the fundamental section. ε= exponent of extraordinary ray

(*i. e.* that passing at right angle to the optical axis and vibrating in the principal section. If the axis c coincides with the optical axis $\mathfrak{a}$ and $\omega > \epsilon$ the mineral is negatively double refractive, while if $c = \mathfrak{c}$ and $\omega < \epsilon$, the mineral is positively double refractive. A thin section of a crystal of either the tetragonal or hexagonal system, if basal, (*i. e.* parallel to O) acts as though isotropous and remains dark in all positions between crossed Nicols. On the other hand, sections taken vertical to O, or parallel to one of the prismatic faces, are dark twice in a revolution and these points occur when the sides of the section are parallel to the principal section of the Nicol's prisms. In such a case the extinction is said to be perpendicular or parallel to the crystallographic axis. Sections inclined to the vertical axis or such as are parallel to a pyramidal face are extinguisned parallel to the vertical axis, but not necessarily to all the sides. Whether the mineral proven to be uniaxial is hexagonal or tetragonal can only be discovered by ascertaining the number of sides of a section transverse to the vertical axis.

In *biaxial minerals* there are two directions without double refraction. Three axes are assumed, each of which is at right angles to the others and has a different amount of elasticity of the ether. These elasticity axes are lettered $\mathfrak{a}$, $\mathfrak{b}$ and $\mathfrak{c}$, in order of elasticity. Two of the optical axes do not correspond with the crystallographic axes, but the two sets of axes form with each other larger or smaller angles. The line which bisects the acute angle = *acute bisectrix*, that which bisects the obtuse angle = *obtuse bisectrix*. The optical axes and both the acute and obtuse bisectrix lie in the same plane, called the optical plane, perpendicular to which is the optic normal. The axis of intermediate elasticity ($\mathfrak{b}$) coincides with the optic normal, while the axes of least and greatest elasticity may coincide with either bisectrix. If a coincides with the acute bisectrix, then c coincides with the obtuse bisectrix and the mineral is negative. If, on the other hand, c coincides with the acute bisectrix and a with the obtuse, it is positively double refractive. α, β, γ are the indices of refraction corresponding to the three axes of elasticity.

In the case of minerals of the *Orthohombic system* the three axes of elasticity $\mathfrak{a} > \mathfrak{b} > \mathfrak{c}$ correspond with the crystallographic axes $\breve{a}$, b, and c, but not necessarily in such a way that $\mathfrak{a}$ always corresponds to $\breve{a}$, etc. a and c are always bisectrices and the optical plane is always parallel to one of the three pinacoids.

The following are possible :

$$\text{If Opt. plane} = \text{O}, \left.\begin{array}{l} \breve{a} = \mathfrak{a},\ b = \mathfrak{c} \\ \breve{a} = \mathfrak{c},\ b = \mathfrak{a} \end{array}\right\} c' = \mathfrak{b}$$

$$\text{If Opt. plane} = i\text{–}\breve{i}, \left.\begin{array}{l} c' = \mathfrak{a},\ \breve{a} = \mathfrak{c} \\ c' = \mathfrak{c},\ \breve{a} = \mathfrak{a} \end{array}\right\} b = \mathfrak{b}$$

$$\text{If Opt. plane} = i\text{–}\bar{i}, \left.\begin{array}{l} c' = \mathfrak{a},\ b = \mathfrak{c} \\ c' = \mathfrak{c},\ b = \mathfrak{a} \end{array}\right\} \breve{a} = \mathfrak{b}$$

Sections parallel to one of the three pinacoid surfaces (usually rectangular) extinguish perpendicularly, *i. e.* become dark between crossed Nicols when one side of the rectangle or one of the pinacoid cleavage lines is parallel to the main section of the Nicol. Distinguished from isometric minerals by the fact that basal sections (parallel O) are not isotropous Only such sections are isotropous as are exactly vertical to the one or the other of the optical axes, which would be the case, accord-

ing to the position of the optical plane, in the plane I–ī, I–ĭ or a prismatic surface. Hence isotropous sections are more rare and less regular than in isometric minerals. Sections parallel to the vertical axis in the zone i–ī, i–ĭ extinguish perpendicularly.

In *monoclinic minerals* only the ortho-diagonal (*b*) coincides with one of the axes of elasticity, the other axes of elasticity form angles with a′ and c′. The optical plane is either parallel or at right angles to the plane of symmetry i–ĭ.

If optic plane = i–ĭ the acute bisectrix $\left.\begin{array}{l} = \mathfrak{c} \\ = \mathfrak{a} \end{array}\right\}$ b=$\mathfrak{b}$
or " " "

then $\mathfrak{c}$ and $\mathfrak{a}$ are inclined toward c and ā.

If optic plane is at right angles to i–ĭ.

the acute bisectrix = b=$\mathfrak{a}$
" " = b=$\mathfrak{c}$
or the obtuse " = b=$\mathfrak{a}$
" " " = b=$\mathfrak{c}$

then $\mathfrak{b}$ and $\mathfrak{c}$ or $\mathfrak{b}$ and $\mathfrak{a}$ are inclined toward c′ and a′.

As a result of the inclination of the axes of elasticity to the crystallographic axes certain of the longitudinal sections are not extinguished when the crystallographic axes coincide with the principal plane of the Nicol's prism. Sections in the zone O. i–ī, all are extinguished perpendicularly, for in this case the orthodiagonal coincides with an axis of elasticity.

In *Triclinic* minerals none of the three axes of elasticity coincides with the crystallographic axes. All sections parallel to the three pinacoid surfaces, therefore, are obliquely extinguished. The angle of extinction in the planes O and i–ĭ is known for most triclinic minerals and forms a ready means of determining these minerals. In thin sections the shape of the section will generally make it clear whether it is or is not parallel to a pinacoid. Accurate measurements of the angle of extinction must be made in cleavage plates parallel to i–ĭ and O.

Twinning Phenomena.

Twins in the regular system cannot be recognized by the polarizer. Twins in the tetragonal and hexagonal systems cannot be recognized unless the axes of the twins are inclined toward each other. If one individual, in such a case, appears dark between crossed Nicols the other may appear colored.

In some cases a crystal individual is made up of alternate lamellæ of the same mineral in different position relative to the axis. Such aggregates are called *polysynthetic twins*. In plagioclase feldspar, calcite and disthene this frequently occurs. In such minerals the adjacent lamellæ will not be extinguished simultaneously under polarized light.

In the rhombic system the twinning plane is usually one surface of a brachydome, a pyramid or a prism. Pleochroism in colored minerals assists in determining the relation of twinned crystals.

In the monoclinic system the plane is often i–i′.

In the triclinic system the polysynthetic form appears very frequently. In plagioclase the twinning plane is generally i–ĭ (albite type). Sections at right angles to this plane in the zone O. i–ī always exhibit the banded colors in polarized light. Twins of this type are impossible in the monoclinic system, because the

plane corresponding to i–ī = i–i′ and coincides with a symmetry plane, hence coalescence in this way would not produce twins. A second type is the pericline type in which the twinning plane is at right angles to the zone O, i–ī.

Pleochroism.

Double refracting minerals have the property of affording different colors when looked through in different directions corresponding to the axes of elasticity. In optically uni-axial crystals there are two such directions (*i. e.* the minerals are dichroic) and the color afforded by looking through in the direction parallel to the vertical axis is called the basis color, that appearing when looked through at right angles to this the axial color. A section of a uniaxial crystal will show no change of color when rotated above the polarizer (analyzer being removed) if the section is parallel to the vertical axis.

In tetragonal and hexagonal minerals, therefore, the directions where greatest change of color occur coincide with the two axes of elasticity, in the orthorhombic system they coincide with the three crystallographic axes as well, but in the monoclinic and triclinic this coincidence seems not to occur.

Use of convergent Polarized Light.

The occular is removed and a condensing lense is placed above the polarizer, between it and the object. Interference figures of a nature varying with the character of the mineral now appear. In regular and amorphous minerals no such figures are produced. The same is true of sections parallel to the vertical axis of the hexagonal and tetragonal minerals. In the transverse (isotropous) sections of *tetragonal* and *hexagonal* minerals an invariable dark interference cross lies in the centre of the field. If the sections is oblique, the cross falls at one side of the centre but is not otherwise altered. A rotation of the stage causes the cross to apparently revolve in the same direction. If the section is so oblique as to fall outside the field a rotation will bring first one limb and then the other into view.

A section of biaxial crystals taken perpendicularly to the bisectrices and placed so that the optical plane coincides with the principal section of the Nicols shows two closed curves enclosing the axial points. These curves are bordered by other curves and crossed by a dark cross. The smaller limb of the cross passes through the axial points and indicates the position of the optical axis plane. The broader limb of the cross is at right angles to it. When the stage is revolved the cross does not remain invariable but is altered to form two hyperbolas which move about the axial points and again form a cross after a revolution of 90°.

The above account, condensed, in the main, from Hussak, will serve to introduce the tables, while the student may be referred for more full explanations to the works of Rosenbusch, Zirkle, Fouque′ and Levy, Cohen and especially Hussak's "Anleitung zum bestimmen der gesteinbildenden Mineralien."

D. Recapitulation of characters of the various crystal systems.

1. *Amorphous* and *regular* minerals are distinguished from all others by remaining dark in all positions between crossed Nicols, while the later may be

distinguished from the former, even in sections, by the regular contour and cleavage.

2. The remainder of mineral species are anisotropous. *Tetragonal* and *hexagonal* minerals have different elasticity in directions parallel and perpendicular to vertical axis c. Rectangular or hexagonal longitudinal sections are extinguished perpendicularly. In convergent polarized light transverse sections exhibit a fixed axial cross, while in longitudinal sections no interference figures appear. Sections obique to the axis show lateral displacement of the optic axis. The fixed axial cross appears to move in the same direction as the stage when revolved. *Hexagonal* are distinguished from the tetragonal forms by the hexagonal and twelve-sided transverse sections.

3. The remaining minerals are optically bi-axial, and in those sections which are isotropous a black band appears in convergent polarized light, which appears to move in a direction opposite to the stage. The axial point may lie within or out of the field (depending on the inclination of the section.) If the band (hyperbola) is bordered with red on the convex side and blue on the concave the dispersion of the axes$=\rho>v$, if the reverse $\rho<v$.

Orthorhombic minerals have both optic axes in a plane parallel a pinacoid. In sections at right angles to the vertical axis extinction takes place parallel and perpendicular to the sides. In sections parallel to the vertical axis extinction is also perpendicular. No interference figure in the third pinacoid section in convergent polarized light.

In *Monoclinic* minerals one axis of elasticity coincides with the orthodiagonal, the others in the symetry plane i–ī or perpendicular to it. Sections perpendicular to the vertical axis are perpendicularly extinguished. Sections parallel to the vertical axis if in the zone O . i–i are extinguished perpendicularly, sections parallel to i–ī are obliquely extinguished. If the optical axial plane is parallel to i–ī none of the pinacoid sections exhibits perpendicular displacement of a bisectrix, but the interference figure is displaced toward the vertical axis.

In *Triclinic* minerals neither of the axes of elasticity coincides with the crystallographic axes. The optical axial plane is not perpendicular to pinacoid surfaces. No pinacoid section is perpendicularly extinguished and none of these sections exhibits perpendicular displacement of the bisectrix.

Explanation of Plate XI.

Fig. 1. Diagramatic section of Lithological Microscope as manufactured by Fuess of Berlin. [See text.]

Fig. 2. Reflecting goniometer of Wollaston, for measuring angles of macroscopic crystals.

Fig. 3. Polysynthetic twins of plagioclase; section parallel i–ī. (From Hussak.)

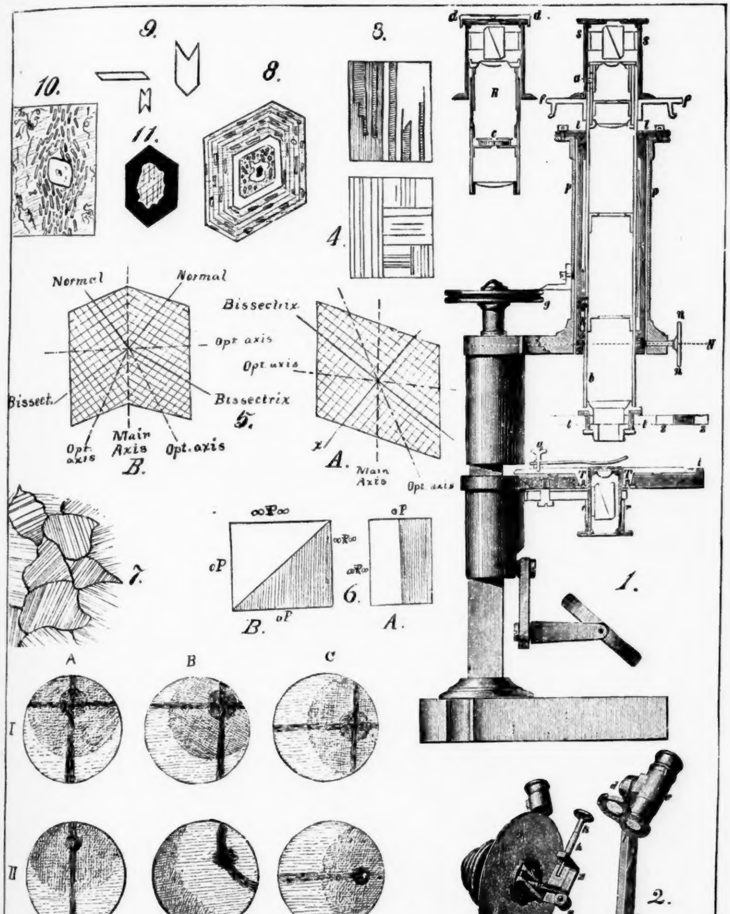
Fig. 4. Plagioclase twinned according to both the albite and pericline type; section parallel i–ī. (From Hussak.)

Fig. 5. Diagram illustrating relation of the optical axes etc., in twins. (In A x = Normal.) It may be more clearly illustrated as follows:— A thin plate of gypsum is taken parallel the principal clinodiagonal. Out of this a

rhombic piece is obtained by using the conchoidal fracture parallel the orthopinacoid and the satiny cleavage parallel to the + hemipyramid. The obtuse angle = 113° 46′ and the acute = 66° 14′. In as much as the optical axes in gypsum lie in the clinodiagonal terminal plane, the surfaces of the plate may be taken as the plane of the optical axes. The conchoidal fracture corresponds with the main axis, and the optical axes above and anteriorly form angles of 23° and 83°. These are represented. By bisecting the acute and obtuse angles we may secure the bisectrix (axis of least elasticity) and the optical normal (axis of greatest elasticity) respectively. The bisectrix forms an angle with the longer diagonal of the plate of nearly exactly 20°. Every ray entering the plate perpendicularly is polarized, forming one ray vibrating in the plane of the bisectrix and another in the plane of the optical normal. In a drawing of the exact shape of the plate these lines are drawn and, in addition, the whole area checked into squares by lines parallel to the bisectrix and the normal (on both sides.) The plate is laid upon the drawing and both are bisected parallel the main axis and one piece is revolved 180° and united by its other edge with the second. The result is an artifical twin of gypsum with the optical determinants all indicated in each (Rosenbusch.) The same method may be applied to illustrate other twins.

Fig. 6 A. Orthoclase twins of Carlsbad type.
B. " Banover type.
Fig. 7. Polysynthetic twins of calcite in marble.
Fig. 8. Section of augite parallel to i-ī, showing zonary structure. (Hussak.)
Fig. 9. Micro-crystals of gypsum (twinned.)
Fig. 10. Inclusions showing fluction structure.
Fig. 11 Hornblende crystal with opaque altered margin. (Hussak.)
Fig. 12. Diagrams of interference figures in convergent polarized light. (Adapted from Fouque′.)

The polarizer and condensor are used, but the occular is removed and the Nicols are crossed. In regular and amorphic minerals no figure is seen. In *uniaxial crystals* in isotropous sections there appears a fixed axial cross with more or fewer concentric colored rings. These latter vary with the thickness of the section. If the section is not exactly at right angles to the main axis the intersection lies out of the centre and revolves with the motion of the section. If the inclination is still greater the intersection falls beyond the field and a revolution of 90° brings first one and then the other limb of the cross into view, I A= a section slightly oblique, I B is the same section revolved 45°, and I C is revolved °90. Biaxial crystals, if taken perpendicular to bisectrix or normal, and if so placed that the opical axis plane coincides with the principal section of the Nicols, show an interference figure consisting of two separate systems of curves whose foci correspond with the two axes. These curves are surrounded each by a lemniscus and a black cross appears with a narrow arm passing through the foci and a broader band between them (II A.) The slender band represents the position of the optical axis plane. When the section is revolved the cross alters its form and at 45° becomes an hyperbola passing about each focus while at 90° the cross reappears but in a position transverse to that formerly occupied.


9.
10.
11.
8.
3.
4.
Normal
Normal
Bissectrix
Opt. axis
Opt. axis
Bissect.
Bissectrix
5.
Opt. axis
Main Axis
Opt. axis
B.
A.
Main Axis
Opt. axis
7.
∞P∞
oP
6.
B.
A.
1.
A
B
C
I
II
III
12.
2.

TABLES FOR THE DETERMINATION OF THE PRINCIPAL

ROCK-FORMING MINERALS.

Translated and Modified from Hussak's

TABELLEN ZUR BESTIMMUNG DER MINERALIEN.

By C. L. Herrick.

Table of Abbreviations.

c = vertical crystallographic axis.
$\breve{a}$ = brachydiagonal in orthorhombic and triclinic systems.
a′ = clinodiagonal in monoclinic system.
$\mathfrak{a}, \mathfrak{b}. \mathfrak{c}$, = axes of elasticity.

$$\left.\begin{array}{ll} \omega = \text{exponent of refraction} & \text{in ordinary ray.} \\ \epsilon = \quad \text{" \quad " \quad "} & \text{in extraordinary ray.} \end{array}\right\} \text{In uniaxial crystals.}$$

$$\left.\begin{array}{ll} \beta = \quad \text{" \quad " \quad "} & \text{in intermediate axis,} \\ \rho = \quad \text{" \quad " \quad "} & \text{in red light.} \\ \upsilon = \quad \text{" \quad " \quad "} & \text{in violet light,} \end{array}\right\} \text{In biaxial crystals.}$$

Disp. = dispersion of axial points.
Symbols of planes essentially as in Dana's Text-book of Mineralogy.

A. Minerals opaque

Name.	*Chem Comp and reactions.*	*Specif. Grav.*	*Crystal*	*Cleavage.*	*Usual combinations and form of Sections.*	*Twins.*
1. *Magnetite.*	$Fe_3 O_4 = Fe O + [Fe_2] O_3$. soluble in H Cl.	4.9–5.2	I	In the plane 1.	Granular and 1. Quadratic and Triangular.	In the plane 1.
2. *Titanic Magnetite.*	$Fe O \begin{cases} Fe_2 O_3 \\ Fe Ti O_3 \end{cases}$ Only distinguishable by chem. analysis.	4.8–5.1	I		1 and granular.	as above
3. *Pyrite.*	$Fe S_2$ Soluble in nitric acid separating sulphur.	4.9–5.2–	I	H	½ [i–2] . Regular hexagons and pentagons	Interpenetrating twins ½ [i-2.]
4. *Titanic Iron.*	$Fe Ti O_3 + [Fe_2] O_3$. Soluble in H Cl with dif. With salt of phosph. gives reaction for Ti.	4.56–5.21	Hex.	R and OR. conchoidal fracture.	Tabular R.oR also –½ R, –2 R and granular grains elongate rather than rounded. Sections chiefly hexag. elongate. In zic-zacked or reticulated forms.	Axes parallel, Polysynthetic twins in R.
5. *Graphite* (and Bitumen.)	C. Bitumenous black rocks, becoming gray on heating.	1.9–2.3	Hex.	O	Very rare, in thin hexagonal plates and *irregular scales*.	
6. *Pyrrhotite* See also Chromite, Pleonast, Specular Iron. } beyond	$Fe_n S_{n+1}$	4.54 4.64	Hex.		Irregularly granular.	

even in thinest sections. *TABLE I.*

Color and lustre.	*Structure.*	*Association.*	*Alterations.*	*Occurrence, etc.*
Iron black, blue-black metallic lustre	Often in beautiful cruciate aggregates, or, as result of alteration, about a mineral or in its cleavage lines.	With nearly all rock-forming minerals, particularly augite, olivine, plagioclose, nephelin. and leucite.	Very often into limonite, forming a reddish brown band about the crystal of magnetite.	1. As primary necessary component of basic eruptive rocks and accessory in nearly all crystallines. 2. As result of alteration of olivine, augite, hornblende and biotite.
"			Into titanite and limonite (Forms the transition to titanic iron.)	Primary, in basalts and crystalline slates.
In reflected light yellow, metallic lustre			Into limonnite.	Rarely as accessory secondary component of altered basic eruptives and (also primary) in crystalline slates.
Blackish brown, metallic lustre. If altered, gray in reflected light.		With plagioclase, augite, hornblende, and olivine.	Into titanite and rutile with specular iron.	In basic eruptives, (particularly granular diabases, gabbros, basalt, pikrit); also in crystalline slates. [Distinguished from magnetite by form of sections and alterations.]
Iron black with metallic lustre				Rarely in cryst. slates, clay-and clay-mica-slates, gneiss, limestone; and as inclusions in staurolite, andalusite, chiastolite, dipyre, etc.
Bronze yellow. Metallic lustre.				Very rare in crystalline slates and contact slates Easily distinguished from pyrite in reflected light by the lustre.

B. Minerals transpa-

1. Minerals crystallizing in the Isometric System.

Name.	*Chemical comp and reactions.*	*Specific Gravity.*	*Cleavage.*	*Unsual combinations & form of sections.*	*Twins.*	*Color and amount of refraction.*
1. *Hauyn Group.* a. Sodalite	3 $(Na_2 [Al_2] Si_2 O_8) + 2 Na Cl$. Cl reaction. Easily soluble in H Cl. leaving a gelatinous residue of $Li O_2$. On evaporation, cubes of salt.	2.13–2.29	i	Granular and i (rarely 1. H) sections quadratic and hexagonal.	Interpen'trating twins in a trigonal-secondary axis.	Colorless, red from presence of $Fe_2 O_3$, greenish or bluish, *blue*.
b. Hauyn and	2. $(Na_2 Ca) (Al_2) Si_2 O_8 + (Na_2, Ca) SO_4$. Reacts for Ca and $H_2 SO_4$.	2.4–2.5	i	Crystals i and 1 as the above	Twins in 1 & as above	Colorless, blue, black.
c. Nosean.	3 $Na_2 (Al_2) Si_2 O_8 + Na_2 SO_4$. Reacts for $H_2 SO_4$ Both are soluble in HCl with separation of gelatinous $Li O_2$	1.279–2.390.		Crystals usually corroded.		Colorless, brown black
2. *Garnet Group.* a Almanadine.	$Fe_3 (Al_2) Si_3 O_{12}$.	3.78 (3 1–4 2)	Imper. in i	i, 2–2 and granular. Sections quadratic, hexagonal or octagonal.		Red, in very thin secti'ns nearly color. $n_p = 1.772$.
b. Pyrope.	(Ca O, Mg O, Fe O Mn O) $Al_2 O_3$ $3Si O_2$ containing chromium.	3 7–3.8	Imper i	Granular.		Blood red.

rent in thin Sections. *TABLE II.*

(*See also amorphous-minerals, Opal and Hyalinamorph.*)

Structure.	*Association.*	*Inclusions.*	*Alterations.*	*Occurrence.*	*Remarks.*
Intimately united with feldspar and hornblend often with a colorless nucleus and red cortical part closed by oxides of iron.	With microcline augite, and mica in syenites. with sanidin and augite in Trachytes.	Fluid inclusions, gas pores. Glassy inclusions, needles of augite.	Becomes turbid from alteration into zeolites.	As primary constituent in syenites and rarely in augite-trachytes as secondary product in cavities of the latter.	These three minerals can only be distinguished with certainty by microchemical qualitative analysis. Hauyn may be distinguished from sodalite by the presence of the characteristic needles of gypsum on evaporation of the nitric acid solution. Sodalite is characized by its chlorine. Hauyn and Nosean are chemically difficult to distinguish and mineralogically may be united.
Very often with a cortical part colored differently from the centre which may be darker, opaque. Often colored by iron in the fissures	Chiefly with leucite, nepheline and augite.	Innumerable gas pores and glass inclusions arranged in bands, minute black grains and needles, often regularly distributed. tables of specular iron.	Alters into an aggregate of double refracting needles and fibres of zeolite and calcite producing a destruction of the color, and by secondary coloration by iron, a change to yellow.	As primary constituent of later eruptive rocks (those containing sanidin as well as those bearing plagioclase) such as trachyte (rarely) phonolite, leucitophyre, tephrite and nephelin and leucite-basalts Occurs also frequently in volcanic trachyte.	
Often united with quartz or feldspar in micropegmatite.	Usually with quartz, orthoclase, biotite, and hornblende.	Cavities having the form of the garnet crystal (negative crystals) Fluid inclusions, quartz grains, rutile grains; often in zonary bands.	Changes on the surface and in crevices to plates of chlorite, or (more rarely) into fibrous hornblende or augite.	Primary constituent in many slaty rocks, frequently in granite, rarely in trachitic rocks	Garnet may be easily distinguished from Hauyn by the color and insolubility in acids
	with olivine and augite.	Very poor.	Very characteristic are zones of augite fibres arranged in groups perpendicular to the surface.	Primary constituent of serpentines.	

Name.	*Chemical Comp. and reactions.*	*Specif. Grav.*	*Cleavage.*	*Usual combinations and form of Sec's.*	*Twins.*	*Color and and amt. of refract*	*Structure.*
c. Melanite	$Ca_3 (Fe_2) Si_3 O_{12}$	3.6–4.3	Incomplete. i	Crystals i		Black, in sections dark brown, quite opaque.	Often with beautiful zonary structure, then often double refracting.
3. *Spinel Group.* a. Chromite.	$Fe\,O\,Cr_2\,O_3$	4.4–4.6	Incomplete. 1.	Granular and 1.		Reddish brown, metalic lustre	Isolated grains often found in basalts with a broad subopaque border.
b. Picotite.	$\begin{matrix} Mg\,O \\ Fe\,O \end{matrix} \left\{ \begin{matrix} Al_2\,O_3 \\ Cr_2\,O_3 \end{matrix} \right\}$	4.8		1. Very minute grains.	Twins in 1.	Becomes transparent with difficulty	
c. Pleonast.	$\begin{matrix} Fe\,O \\ Mg\,O \end{matrix} \left\{ \begin{matrix} Al_2\,O_3 \\ Fe_2\,O_3 \end{matrix} \right\}$	Over 3.65 (3.8–4.1)				Dark green	
d. Hercynite.	$Fe\,O.\ Al_2\ O_3$ Insoluble in acids and unaffected by H Fl.			1.		Frequ'nt with quartz, orthoclase, and mica	
4. *Analcite.*	$Na\,2\,(Al\,2)\ Si_4\,O_{12} + 2$ aq. Soluble in H Cl with sep of $Si\,O_2$ jelly.	2.1–2.28	Incomplete. (According to Tschermak H.)	Chiefly compact granular, in cavities 2 2		Colorless white, $n_p =$ 1.4874	Often double refractive and with a distinct zonary structure generally cloudy, combined with plagioclase
5. *Fluorite.*	$Ca\,Fl_2$. Decomposed by concentrated $H_2\,SO_4$ with liberation of H Fl.	3.1–3.2	Complete 1.	Occurs in rocks only in the form of minute angular grains.		Blue, colorless, very strongly refractive.	Penetrating feldspar, and irregularly distributed in the magma.
6. *Perowskite.*	$Ca\,Ti\,O_3$. Decomposed in $H_2\,SO_4$ but not H Cl.	4.0–4.1	H.	In irregular branching and angular forms, generally in distinct octahedrons.	Very rare. Interpenetrating twins.	Violet gray, reddish gray brown. In strong relief.	Characteristic is the rough surface of a section. Grouped as inclusions in melilite or olivine. Often exhibiting double refraction. Colors of polarization not bright.

Mineral appearing regular

TABLE III.

Association.	*Inclusions.*	*Alterations.*	*Occurrence.*	*Remarks.*
With augite sanidine, nepheline, hauyn, and leucite.	Very poor, augite and apatite needles, glass inclusions.		Primary component of phonolite, leucitophyr, and volcanic products.	Compare Chromite.
With olivine and augite.			Primary accessory component. In olivine rocks, serpentine and basalts. Picotite often as inclusions in olivine.	Very similar to melanite; when in grains only chemically distinguishable. Melanite is, however, almost always crystallized, and so easily distinguishable. a and b can only be distinguished chemically. The spinels may be distinguished from magnetite by transparency (in very thin sections) and by the insolubility. 3 c and 3 d can only be distinguished chemically.
Most rarely with olivine and augite.			As above but rarely, more often in granulites and in metamorphic (contact) rocks.	
With plagioclase augite or hornblende.	Poor in inclusions. Fluid inclusions, needles of apatite.		Rare in later basic eruptives (either primary or as product of alteration of nepheline). In cavities in phonolites, trachyte andesites, basalt, as alteration product.	
With quartz, orthoclase and biotite.	Fluid inclusions.		Very rare; secondary in quartz porphyry.	
With nephiline, melilite, augite and olivine.	Very poor.		In nepheline–leucite– and melelite-basalts.	Distinguished easily from spinel by color and optical anomalies, and from garnet by its crystalline form.

= Leucite. See below.

II. Double-refractive minerals.

A. Uniaxial optically.

1. Tetragonal system. a. Double refraction positive.

Name.	*Chemical comp. and reactions.*	*Specific gravity.*	*Cleavage.*	*Usual combinations and form of sec's.*	*Twins.*	*Character and amount of double refraction.*	*Polarization colors.*
1. *Leucite*	$K_2 (Al_2) Si_4 O_{12}$.	2.45–2.5	Incomplete prismatic i–i and O.	Grains and (generally) crystals 1. 4–2. Sections octagons frequently with rounded angles, more rarely hexagons.	2–i, polysynthetic twin striations in these planes, crossing at right or oblique angles.	Small individuals without twin-striations appear isotropous. In converg. pol. light no evident axis figure. Double refraction feeble, positive.	Not brilliant, bluish gray.
2. *Rutile* (Nigrine Sagenite.)	$Ti O_2$. *Ti*–reaction with phosphorous bead. Insoluble in acids.	4.2–4.3 (4.277)	I and i–i	I. i–i, 1 granular; generally, however, in minute elongate needles and crystals. The prisms are striate parallel to axis c.	Very frequent and characteristic in the plane 1–i; 'knee shaped' with an angle of 114°–25′; also tissue of fine needles which cut each other at an angle of about 60° (*sagenite*), also cordate twins in 3–i, frequent.	Crystals usually too small for determination with condenser. Double refraction strong, positive.	None particularly brilliant.
3. *Zircon*	$Zr + O_2 + Si O_2$ $H_2 SO_4$ decomposes; other acids without effect.	4.4–4.7	Incomplete 1 and I.	1, i–i, 3–3; numerous combinations; almost solely in minute but sharply defined crystals.	Very rare 1–i.	Positive, very strong.	Very brilliant, emerald-green, hyacinth-red and irridescent.

II. Double-refractive minerals. *TABLE IV.*

A. Uniaxial optically.

1. Tetragonal system. a. Double refraction positive.

Color and amount of refraction.	*Pleochroism.*	*Structure.*	*Association*	*Inclusions.*	*Alterations*	*Occurrence.*	*Remarks.*
Colorless, $\omega=1.508$ $\varepsilon=1.509$		Aggregate of spherical crystals to form a large crystal. Zonal and radiating arrangement of the inclusions. Large corroded crystals of the first order, and minute sharply defined crystals of second order, the latter often penetrating augite	With augite, olivine, plagioclase, and sanidine.	Inclusions zonary or radiating, or collected in a central aggregate, consisting of minute glassy particles, gas pores, augite needles, etc as well as of Hauyn, augite, apatite and melaite.	Into an aggregate of colorless or yellowish, finely radiating fibres or grains of zeolites, rarely pseudomorphs of analcite after leucite.	Primary, essential constitu'nt with sanidine etc. in leucitophyres, leucite-tephrites, and basalts, also with nepheline and plagiolase. Only found in later basic eruptives.	The foregoing characters make it easily recognizable unless It occurs in very minute grains in the magma, when it may be difficult to distinguish it from interspersed colorless areas of the glassy basis. In this case to be recognized microchemically.
Hon'y yellow to reddish brown, grains often opaque or merely transluc'nt (*Nigrine*), in which case with (incomplete) metallic lustre.	Not particularly noticeable	In biotite frequently very regular compounded into "sagenite" forms, also united to titanic iron. Often as an inclusion in the accompanying minerals, particularly garnet and omphacite.	With quartz, potash feldspar, garnet, hornblende, omphacite	Very poor.		As primary accessory component abundant in nearly all crystalline slates, particularly those bearing hornblende and augite, as amphibolites and eklogit's. Also as secondary dec'mposition product of titanic iron. frequent in clay slates.	Easily distinguished from zircon by the polarization colors, color and tendency to twin.
Colorless, wine yellow. Refraction strong, hence dark contoured (by total reflection). $\omega=1.92$ $\varepsilon=1.97$	Not noticeable.	Like rutile, one of the first formed components of rocks and therefore frequent as inclusions in the others.	With quartz, orthoclase, biotile, hornblende, augite.	Fluid inclusions, needle-shaped cavities, and long unidentified needles.		Primary accesory component of granite, syenite, quartz-porphyry, trachytes and many other eruptive rocks, but rare. More frequ'nt in crystalline slates with rutile.	Well characterized by the crystalline form, polarization colors, and strong double refraction.

b. Double refraction

Name.	*Chem. Comp and reactions.*	*Specif. Grav.*	*Cleavage.*	*Usual combinat's and form of the Sections.*	*Twins.*	*Char. and am't of the d'bl. refract*	*Polarization Colors.*	*Color and Amount of refraction.*
4. *Anatase.*	As in rutile.	3.83–3.93	O and 1.	Apex 1.		As in rutile.	Like rutile.	Dark, lavender blue.
5. *Mejonite g'p.*								
a Mejonite.	$Ca_6 (Al_2) Si_9 O_{36}$.	2.734–2.737.	Complete. i–i	Crystals I. i–i. 1 and large grains or long columnar individuals.				ω=1.594–1.597 ε=1.558–1.561 Colorless, white.
b. Scapolite.	$R_3 (Al_2) Si_6 O_{21}$ ($R=Ca\ Mg\ No_2$) Soluble in H Cl separating pulverent $Si\ O_2$	2.63–2.79				Double refraction negative, rather strong.		ω=1.566 ε=1.545
c. Couseranite and Dipyre	Similar to scapolite; rich in alkalies, $H_2 O$. Unaffected or but little affected by acids.	2.69–2.76 (2.613) 2.62–2.68	i–i. fracture in O.	Long columns I. i–i. rounded or frayed out at the end.		As in scapolite, rather strong.	Rather brilliant.	Bluish, in sections, colorless, pelucid; becomes black from inclusions ω=1.558 ε=1.543
d. Melilite.	$(Ca, Mg. Na_2)_{12} (Al_2 Fe_2)_2 Si_9 O_{36}$ easily soluble in H Cl with separation of gelatinous silica.	2.90–2.95	Parallel O and I.	Almost always in crystals; thin plates predominatingly O. I. i-i Irregular grains. Sections mostly linear, rectangular or rarely rounded.	Rarely interpenetrating twins with the principal axes at right angles	Feeble.	Not very brilliant, if yellow and fibrous it affords the coloration of an aggreate, if colorless the polarization colors are bluish gray.	Usually citron yellow, *honey yellow*, also colorless, to yellowish white.

negative. **TABLE V.**

Pleochroism.	*Structure.*	*Association.*	*Inclusions*	*Alterat'ns*	*Occurrence.*	*Remarks.*
Like rutile.		With quartz, orthoclase, biotite			Very rare in granite, quartz-porphyry. and crystalline slates.	
	Scapolite seems to frequently replace plagioclase and to be formed by its decompositi'n	With sanidine sodalite, and augite. With quartz, plagioclase calcite. augite. garnet, rutile, & titanite.	Poor. Fluid inclusions. Rutile occurs in scapolite.	Confused fibrous; changed into calcite.	Primary accessory component, rarely in trachytic rocks. Rare, in crystalline slaties, with plagioclase as a (secondary?) accessory component.	Scapolite is easily distinguished from orthoclase and calcite by its optical peculiarities and cleavage. Mejonite is recognized by its crystal form.
	Crystals in limestone, often very rich in inclusions	With calcite, actinolite and mica	Very rich, particles of carbon, quartz grains, & plates of muscovite, irregularly distribt'd	Fibrous decomposition with formation of calcite in the crevices.	As contact mineral in metamorphic limestone, very rare.	Easily distinguished from andalusite, optically, and from chiastolite by its structure.
Rectangular longitudinal sect'ns show a very feeble dichroism.	Rectangular longitudinal sections show striations and fibrous structure parallel to the shorter side (i. e. axis c); these are very fine spindle-shaped cavities which appear as minute circles when cut at right angles to the axis c, (so-called "spile structure") Coalesced with leucite or pentrating it.	With nepheline, leucite, augite and olivine.	Poor.	The fibrous structure is due to change into zeolitic substances.	As primary ingredient of the nepheline- and leucite-basalts replacing nepheline. often very abundant.	Easily recognized by the crystal form and fibrous structure. Easily confused with nepheline if colorless, but does not show hexagonal isotropous sections. Often only distinguished from serpentine by the light yellow color and the absence of remains of olivine. From biotite distinguished by the lighter color and absence of strongly dichroic longitudinal sections.

2. *Minerals crystallizing in*

a. Double refrac-

Name.	*Chemical comp. and reactions.*	*Specific Gravity.*	*Cleavage.*	*Unsual combinations & form of sections.*	*Twins.*	*Char. and amount of dbl. refract*
1. *Quartz.*	$Si\ O_2$. Insoluble except in H Fl.	2.65.	Incomplete in R. Sections full of cracks due to conchoidal fracture.	Granular or crystals R.–R or iR. R.–.R. Usually in larger individuals. Sections are regular hexagons with two parallel sides longer than the others, or in rhombs, never as microliths.	With parallel axes. Rarely twinned when forming a component of rocks.	Feeble.
1. *Tridymite.*	As above.	2.282 2.326.	Inc'mpl'te O.	In very minute thin plates O and I.	Frequent. Twinning plane a surface of ⅙ and ¾.	Very feeble.

On account of the minute size of the crystals found in rocks accurate determination is usually impossible. Microscopic tridymite behaves in parallel polarized light as though hexagonal.

the Hexagonal System.

tion positive.

Structure.	*Association.*	*Inclusions.*	*Alterations.*	*Occurrence.*	*Remarks.*
Often colored by Fe_2O_3 in crevices, or rendered confused by inclusions. Quartz in eruptives often corroded Coalesces with orthoclase to form micropegmatite frequently in granites In porphyritic eruptives also sphærolitic.	With orthoclase (and sanidine) more rarely with plagioclase, biotite, hornblende, and augite. Never occurs in augitic olivine-bearing rocks or in nepheline–or leucite bearing rocks as a primary constituent. With muscovite and biotite.	Poor in mineral inclusions Apatite columns. In the fragmental states and granites rich in fluid inclusions and long brownish or blackish curved needles. In eruptives rich in glass inclusions and gas pores.	There are none although changes due to molten magma are not rare in quartz from eruptive rocks See corrosion and secondary glass inclusions.	I. Primary constituent. (a) In eruptive rocks as component of the first order as macroscopic fragments in grains and crystals in granite with fluid cavities and in quartz–porphyry and trachytes with glassy inclusion, and also as accessory in many other eruptives. As constituent of the second order in the magma of these rocks (b) In nearly all crystalline slates. II. *Secondary product by alteration of silicates ; in diabase in granular aggregates, and in veins of many rocks. III. In water worn grains in many clastic rocks. IV. Forming a simple rock, as quartzite etc.	When granular, often deceptively like sanidine, but easily distinguished from isotropic sections of it. Distinguished from nepheline and apatite by insolubility ; from corundum by character of double refraction, from calcite by cleavage and twinning.
Usually in aggregates of minute thin hexagonal or irregular superimposed plates. Often in the vicinity of the feldspar or in large masses in the magma.	With quartz, sanidine, plagioclase, augite, biotite, and hornblende. Secondary with opal and chalcedony.	Fluid inclusions.	*Occurrence.* Primary component and secondary in rhyolites, trachytes, hornblende–and augite-anderites. In general, more frequent in later, acid eruptives and more rare in older basic eruptives. Secondary in cavities of these rocks and, in that case, usually in large plates.		Microscopic tridymite may be recognized by the form of its aggergates, while for the larger masses the optical characters serve to identify it.

b. Double refraction

Name.	*Chemical Comp. and reactions*	*Specif Gravity.*	*Cleavage.*	*Usual Combinations and form of the Sections.*	*Char. and Amt. of dbl. refraction.*	*Colors of Polarization*	*Color and Amount of refraction.*
1. *Calcite.*	$CaCO_3$. soluble with effervescence with H Cl. In acetic acid soluble.	2.6–2.8 (2.72)	Incomplete. R.	Only in irregular grains and crystal aggregates. Polysynthetic twin marking in $-\frac{1}{2}$ R.	Very considerable, negative.	Generally not intense, gray, but brilliantly irridescent like talc epecially when in small grains.	Colorless, white to gray. $\omega = 1.6543$ $\varepsilon = 1.4833$ (Absorbtion feeble.)
2. *Dolomite.*	(Ca Mg) CO_3 Less easily soluble.	2.85–2.95	As above.	Grains and R.		As above.	As above.
3. *Magnesite.*	$MgCO_3$. still less soluble	2.9–3.1	As above.	As above.		As above.	As above.
4. *Siderite.*	$FeCO_3$ easily soluble with effervescence.	3.7–3.9	As above.	As above.		As above.	Yellowish brown.
5. *Nepheline G'p.* a. Elaeolite.	$(Na\,K)_2\,(Al_2)\,Si_2\,O_8$ Soluble easily in H Cl with separation of gelatinous silica, on evaporat'n cubes of salt.	2.65 (2.591)	Incomplete large fissures	Only in large grains.		Chiefly bluish green not brilliant.	Green, reddish brown, oily lustre in sections colorless.
b. Nepheline.		(2.58–2.65)	Incomplete. O and I	Hexagonal and rectagonal! In minute crystals I . O short columnar and minute irregular grains.	Double refraction feeble.	Similar to fieldspar strips in very thin sections	Colorless, transparent $\omega = 1.539$-1.542 $\varepsilon = 1.534$-1.537
c. Cancrinite.	Soluble with effervescence separating gelatinous silica	2.448 –2.454	Incomplete I	Large irregular grains.		Rather brilliant. Aggregate polarization	Citron yellow, almost colorless in sections.
d. Liebenerite.	Incompletely dissolved by H Cl.	2.799 –2.814	Very Incomplete I.			Very distinct aggregate polarization.	Oil green, in sections colorless, *white.*

Nepheline differs from apatite in its incomplete cleavage, microchemical reactions and crystal form, since apatite often exhibits, besides I and O, the plane 1, and occurs in long columns. Quartz never occurs in so minute crystals. Feldspar bands are long and twinned. Melilite has no hexagonal sections.

negative. *TABLE VII.*

Structure.	*Association.*	*Inclusions.*	*Alterations.*	*Occurrence.*	*Remarks.*
Usually in granular aggregates in cavities, in bandsorveins. Also in irregular grains & simple individuals between the constituents.	In nearly all rocks which bear augite, hornblende, biotite and plagioclase.	Fluid inclusions, very poor in mineral inclusions.	None.	Primary and sole component of limestone, etc. Not known certainly from eruptives except as secondary product, particularly of bisilicates and mica. In crystalline slates as both primary and secondary.	Well characterized by rhombohedral cleavage and twin-lamellation. When in small grains not easily determined Reliance must be put upon the solubility and colors of polarization.
As above.					Without the polysynthetic lamellation.
As above.	With serpentine.			With olivine and serpentine as product of alteration.	Magnesite and siderite only chemically distinguishable from calcite.
As above.	As calcite.			In concentric shells and radiating spheres in andecite, etc., as product of alter'n	
Irregular grains coalesced with the other constituents.	With sodalite microcline, hornblende, and titanite.	Poor, frequently colored green by particles of hornblende.	Fibrous transition into zeolites.	Primary essential component of older eruptives, in elæolite-syenites.	Easily recognized macroscopically solubility and Na reaction forming good characteristics.
In crystals or aggregates of minute irregular grains.	With leucite, augite, or with sanidine and augite, or with hornblende and titanite	Frequently augite-microlites arranged parallel to the surfaces.	Usually unaltered in phonolites or polarizing like an aggregate and cloudy, showing passage to zeolites	Primary component of later eruptives, nephelinites, nepheline-and leucite-basalts, phonolites and tephrites.	* See below.
Fibrous, coalesced with nepheline and orthoclase.	As in elaeolite.	Poor, iron oxide flakes, as in elaeolite.	Fibrous decomposition forming calcite. (Cancrinite seems to be but an alteration after nepheline.)	As elaeolite, rare.	Distinguished from elæolite only macroscopically by amt. of Ca CO_3
Only as fragments in macroscopic crystals.	With flesh colored orthoclase and mica.		Apparently only a total alteration of nephelin(?) or cordierite(?), largely consists of minute muscovite scales	Rare in orthoclase porphyry.	Easily recognized by crystal form and alteration.

Zeolites usually show their secondary character. Tridymite has no such short rectangular longitudinal sections. When nepheline appears as an aggregate of minute grains it can be distinguished from colorless glass-masses or quartz or othoclase aggregates by micro-chemical methods.

Name.	*Chemical comp. and reactions.*	*Specific gravity.*	*Cleavage.*	*Usual combinations and form of sec's.*	*Twins*	*Char. and amount of d'bl refract*	*Polarization colors.*
6. *Apatite*	$Ca_5\ P_3\ O_{12}$ Cl $Ca_5\ P_3\ O_{12}$ Fl. Dissolves in acids, gives phosphoric acid reaction.	3.16-3.22	Crystals, more rarely granular. Parallel O and I, incomplete. *Fracture* ‖ O very perfect, hence the needles are found broken into sections	I, 1 and more rarely O, generally long columns.		Not strong	Usually not brilliant, as in nepheline.
7. *Corundum.*	$(Al_2)\ O_3$ Insoluble	3.9-4	R and oR.	i-2.oR R and grains. Hexagons and rectangles which are truncated at the angles by R.	Rare in rocks.	Strong.	Very brilliant.
8. *Tourmaline.*	Complicated. Boric acid reaction Not attacked by acids.	3.059	Incomplete R and i-2. Very complete fracture ‖ oR.	Almost alw'ys crystalline R, i-2.½ (i-R.), transverse sections triangles, hexagons nonagons. Often hemimorphic parallel to main axis, oR below, R above.		Strong.	Rather brilliant between red and brown.
9. *Specular Iron*	$Fe_2\ O_3$ Easily soluble in HCl.	5.19-5.28.	R oR. Not characteristic in microscopic individuals.	Tabular plates oR. i-2 and irregular plates.	With axes parallell. Interpenetration twins with re-entering angles.	Not definable on account of occurrence.	Very feeble.

Minerals seeming to crystallize in the Hexagonal System.

1. *Biotite.*
2. *Chlorite.*

} See Monoclinic System.

TABLE VIII.

Color and amount of refraction.	*Pleochroism.*	*Structure.*	*Association*	*Inclusions.*	*Alterations.*	*Occurrence.*	*Remarks.*
Colorless, white, reddish, green black through numerous inclusions not transparent as nepheline $n = 1.657$	If colored, with evident dichroism.	In irregular grains or long often slender columns, frequently broken into joints by basal fracture Inclusions. Only as accessory component. As inclusions particularly frequent in bisilicates, hornblende and biotite.	Known to occur in nearly all rocks.	Glass inclusions, gas pores Very characteristic are black or brown needles, or minute grains filling the entire crystal, giving the cross section particularly a remblance to hauyns. Central inclusion of glass etc. often assuming the shape of the crystal.	Always unchanged.	Accessory in nearly all rocks. One of the first minerals to separate from the magma.	Distinguishable from hauyn in the longitudinal section and basal fracture; from olivine by optical peculiarities and fracture.
Colorless, *sky blue*, spotted, also brown through inclusions. Stands out well in sections being strongly refractive. $\omega=1.768$ $\varepsilon=1.760$	When colored, very strong ω=sky blue ε=sea green.	Surface of sections rough. In round grains or short columns. Zonary struct're, blue nucleus and colorless cortical layer.	With quartz, orthoclase and biotite, Pleonast, and andalusite.	Very poor, fluid and glass inclusions; zircon; dusty brown inclusions (in "common corundum.")		Very rare. Contact mineral in metamorphic slates and trachytic ejections.	If granular, similar to apatite yet recognized by colors of polarization.
Chiefly bluish gray, brown. $\omega=1.64$ $\varepsilon=1.62$	Very strong dichroism. ω=dark blue, brown to black. ε=light blue to brown.	Macroscopic and *very minute* crystals, rarely in grains, as in certain metamorphic rocks In granites coalesced with quartz in grains Large individuals often frayed out in a radiating manner at the end.	With orthoclase and muscovite in granite. With quartz, orthoclase, mica and other accessory minerals, such as staurolite and garnet.	Very poor. Fluid inclusions.		Primary component, frequent. Granular, accessory in many crystalline slates and in clastic rocks. Characteristic in contact with eruptive rocks	Easily recognized by crystal form and pleochroism. Distinguished from hornblende by optical characters.
Iron black with metallic lustre. In thin plates blood red, also yellowish red and brown violet.		Only in plates in crevices of minerals by infiltration. *Secondary* except perhaps in basalts.	In nearly all rocks particularly with decomposed biotite, hornblende, augite, magnetite, of which it is a product of decomposition.		Into pulverent limonite	(See under association.)	Easily recognized.

II. Biaxial minerals.

1. Rhombic System.

a. Sections parallel O without interference figures.

Name.	*Chemical comp. and reactions.*	*Specific Gravity.*	*Cleavage.*	*Unusual combinations & form of sections.*	*Twins.*	*Optical determinants.*	*Double refraction.*	*Colors o polarisa tion*
1. *Olivine* (Crysolite)	$Mg_2 Si O_4 + Fe_2 SiO_4$ Rather easily soluble in HCl with separation of gelatinous silica.	3.2–3.4	Complete in i–ī, in complete in i–ī, con choidal fracture. In sections usually curved crevices.	Tabular crystals I. 1–ī. i–ī, hexagonal sections. I=139°2′ 1–ī=76° 54′, or large rounded grains.	Very rare 1–ī and interpenetrating.	Acute bisectrix at right angles to i–ī. ă=c, b=a, c′=b; $\rho<v$.	Positive, strong.	More br liant tha augite.
β. sections parallel O with interference								*figures,*
aa. disappearance of positive								*bisectrix*
1. *Sillimanite.*	$Al_2\ Si\ O_5$. Insoluble.	3.23–3.24	Parallel i–ī; fracture of thin needles in O.	Columnar. I=111°		Optical axis plane ‖ i–ī. acute bisectrix at right angles to O; c′=c b=a ă_b	Strong, positive.	Very br liant About in musc vite.
2. *Staurolite.*	$H_2\ R_3\ (Al_2)_6\ Si_6\ O_{34}$. R=3Fe+Mg. Insoluble.	3.34–3.37	i–ī complete; I incomplete; fracture in O.	Rarely in irregular grains, crystals I. i–ī. O I=128° 42′.	Interpenetrating twins, vertical axes inclined or vertical, rarely microscopic.	As above, (dispersion feeble $\rho>v$).	As above. Pleochroism strong c=dark brown a=b=light yellow.	As abov
3. *Enstatite.*	$Mg\ Si\ O_3$ Soluble very slightly.	3.1–3.29 (3.153).	I complete; i–ī i–ī longitudinal sections seem fibrous fracture. O.	Long columnar I. i–ī. i–ī m–ī, 8-sided cross sections with two pairs of longer sides, like monoclinic augite.		When I=92° in front the optical axis plane=i–ī acute bisectrix at right angles to O, c′=c b=b ă=a.	Positive rather strong, feebler than in monoclinic augite.	Very br liant.

Colors of polarisation	*Color and inex of refraction.*	*Structure.*	*Association*	*Inclusions.*	*Alterations*	*Occurrence*	*Remarks.*
More brilliant than augite.	In sections colorless. rarely green. Strongly in relief. $\beta = 1.678$.	Surface of sections rough, changes in the crevices to reddish, brownish, or greenish serpentine and has picotite inclusions. Either well defined crystals or fragments or irregular grains.	With olivine, plagioclase, nepheline, leucite, hornblende, and biotite Almost never with primary quartz or orthoclase	Rather poor, aside from minute picotite octahedrons, glass and, more rarely, fluid inclusions, magnetite	Usually into serpentine, also into a brown, fibrous aggregate. Pseudomorphs of calcite after olivine in picrite. Formation of limonite.	As primary essential component of all basic rock. In olivine stone and picrite, melapyre, olivine-gabbro, olivine norite, olivine di'base Also in certain micaceous porphyries.	Distinguished from quartz in isotropous sections, from zoisite by crystalline form (not in needles) and colors of polarization, from augite by cleavage, from sanidine by rough surface and brilliant colors of polarization.
figures, double refractive positive. bisectrix (+) in O.							
Very brilliant About as in muscovite.	Light or dark yellowish brown, strong relief. $\beta\rho = 1.66$.	In exceedingly slender long needles often numerous or felted in parallel masses in quartz, cordierite, etc.	With quartz orthoclase, biotite, and muscovite.	Very poor; fluid inclusions.		As primary, accessory component of crystalline slates; rare	Distinguished from zoisite by double refraction and polarization colors, from andalusite by double refraction and cleavage.
As above.	Light or dark brown. $\beta\rho = 1.7526$.	Large and small crystals, characterized by many inclusions.	With quartz, orthoclase, mica, and garnet.	Minute quartz grains, bitumen, specular iron.		Primary accessory in crystalline slates, particularly mica schist	Easlly distinguished by pleochroism.
Very brilliant.	Colorless to green, strong relief.	In irregular long columns. Often coalesced parallel to c with monoclinic augite.	With plagioclase, olivine, and monoclinic augite.	Very poor.	Into serpentine with formation of talc. Into basite.	In basic p'rphyritic eruptives as essential and accessory. With olivine stone. Rarely in quartz bearing rocks, as quartz porphyry, diabase porphyry also in gabbro and norite	Distinguished from olivine by fibrous structure parallel to c. It does not occur in minute needles as si limanite. Differs from the following only in absence of iron.

Name.	*Chem. Comp and Reactions*	*Specif. Grav.*	*Cleavage.*	*Usual combinations and form of sec's.*	*Twins.*	*Optical determinants.*	*Double refraction.*
4. *Bronzite.*	m ($Mg\,Si\,O_3$) + n [$Fe\,Si\,O_3$], Insoluble.	3–3.5 (3.12-3.25)	Complete I and partial in i–ĭ.	Long columnar I . i–ĭ i–ĭ prevailing. ⅔, ⅔-ĭ, very similar to mono clinic augite	Repeated twinning in ¼-ĭ giving the cleavage plates in i–i a wavy appearance. "Knee"-shaped twins in m–ĭ in stellate groups occur rarely in porphyritic eruptives.	As in enstatite.	Positive. Sections paralel to O. & i–ĭ show simply an open cross with traces of Lemnisci. Sections perpendicular to an optical axis show one ring or none
5. *Anthophyllite.*	n $Mg\,Si\,O_3$ + $Fe\,Si\,O_3$ Insoluble.	3.187–3.225	i–ĭ I i-ĭ, incomplete.	In foliaceous masses rarely in crystals. Sections as in monoclinic hornblende.		Optical axial plane parallel i–ĭ acute bisectrix at right angles to O c′=𝔠 b=𝔟 ă=𝔞	Positive, strong.
					bb.	Disappearance of obtuse	
1. *Hypersthene.* 2. *Protobasite* and *basite.* (See below.)	As in Bronzite but with more iron.	3.3–3.4	I complete i–ĭ conchoidal fracture i–ĭ incomplete I= about 92°	Large irregular grains and minute columns with the combinati'n I . i–ĭ. i–ĭ, also ½-ĭ. 2–ĭ 3-2–3-2.	Knee-shaped twins as in bronzite.	Opt axis plane parallel i–ĭ obtuse bisectrix at right angles to O acute bisectrix at right angles to i–ĭ c′=𝔠 b=𝔟 ă=𝔞 Large axial angle.	Parallel to O positive, to i–ĭ negative, feebler than in mono-clinic augite.

Protobasite (diaclasite) and basite have the same composition as bronzite + H_2O. In sharply defined crystals, columnar grains and irregular scales. Cleavage i–ĭ and I. Opt. axis plane ‖ i–ĭ. obtuse bisectrix at right angles to O, the acute bisectrix to i–ĭ. Specif. grav. of protobasite 3.054. of basite 2.6–2.8; the former is is light yellow, with rather brilliant polarization. In gabbro and porph. augite-bearing plagioclase rocks, changes to basite which is dirty light green, and is always a product of decay of rhombic augite.

TABLE X.

Colors of polarization.	*Color and Refraction.*	*Structure.*	*Association.*	*Inclusions.*	*Alterations.*	*Occurrence.*	*Remarks.*
Interferance colors not nearly as brilliant as in monoclinic augite.	β=1.639 Dark brown. Slight pleochroism	Partly in large irregular grains in coarsely granular rocks partly in sharply defined crystals in porphyritic eruptives.	With olivine, plagioclase, monoclinic augite, magnetite, as enstatite	Inclusions of brown rectangular plates or opaque needles parallel to i–ī.	Into a green fibrous aggregate as basite with separation of $Fe_3 O_4$ or $Fe_2 O_3$.	As enstatite. Often replacing monoclinic augite as essential. Also in later basic eruptives and coarsely granular older rocks.	Distinguished from augite only by study of transverse section and perpendicular extinction in longit. sections from hypersthene by pleochroism and d'ble. refract., from hornblende and biotite by absence of strong pleochroism.
Brilliant.	Dark brown $\beta\rho$=1.636, relief faint strongly pleocroic. Parallel to c greenish yellow, at right angles reddish brown.	Inclusions as in bronzite, longit sections seeming fibrous on account of cleavage.	With olivine, plagioclase, augite, and hornblende.	Minute brown and green regularly arranged scales like mica. Otherwise poor in inclusions, magnetite.		Very rare, accessory as secondary product of decomposition of olivine in gabbro and olivine stone.	Distinguishable from biotite by cleavage amt. of pleochroism and size of axial angle.
bisectrix (+) in O.							
Rather brilliant. cf. Bronzite.	Light or dark brown, black by inclusions. β=1.639 Pleochroism strong. Axial colors $\mathfrak{a}$= hyacinth red $\mathfrak{b}$=reddish brown. $\mathfrak{c}$=grayish green. $\mathfrak{c}' > \ddot{\mathfrak{a}} > \mathfrak{b}$.	In large irregular grains in granular older rocks, in small crystals in later porphyritic eruptives.	With plagioclase, olivine, and monoclinic augite.	In the granular varieties innumerable brown or violet rectangular scales in the cleavage lines parallel i–ī. In crystals regularly arranged opaque needles otherwise poor.	Decomposes into fibrous aggregate parallel to axis c′, with dirty brown or green color, as enstatite.	In grains in gabbro, norites, in later eruptives, particularly augite andesite and in feldspathic basalts poor in olivine as primary necessary component and with monoclinic augite.	Distinguished from monoclinic augite only by effects of convergent polarized light, from bronzite by strong pleochroism.

The three rhombic augites—enstatite, bronzite and hypersthene are chiefly distinguished by variation in amt. of iron, accompanying which a variation in angle of the optical axes lying in the plane i–ī. Rhombic augites distinguished from monoclinic by inferior brilliancy of polarization and feebler double refraction. Isotropous sections perpendic. to opt. axis in monoclinic augite exhibit two or three rings and bands while the rhombic at most one and also lacks polysynthetic twinning ‖ i–ī.

In sections ∥ to O the axial interferance

aa. Disappearance of the acute

Name.	*Chem. Comp. and reactions.*	*Specif. Grav.*	*Cleavage.*	*Usual combinations & form of Secs.*	*Twins*	*Opticial determinants*	*Double Refract*	*Colors of Polariz'n.*
1. *Andalusite.* Chiastolite is a variety with sp grav. 2.9–3.1, characterized by regularly arranged particles of carbon in the centre and four angles Occurs in metamorphic slates.	$(Al_2) Si O_5$ Insoluble.	3.10–3.17	Prismatic in I. Incomplete in i–ī, i-ī and 1–ī. I=90° 50′. Fracture ∥ O.	Long columns I . O. 1–ī, more rarely granular. Transverse sections quadratic, longit. sections rectangular		Opt. axis plane ∥ i–ī. Acute bisectrix ⊥ O. c=𝔞 b=𝔟 ă=𝔠 Axial angle considerable.	Negative, strong.	Brilliant.
2. *Cordierite.* (Dichroite) Pinite is a decomposition product of the above, consisting of minute fibres and scales. *	$Mg_2 (R_2) Si_5 O_{18}$ $(R_2) = Al_2 Fe_2$ Almost insoluble.	2.59–2.66	i–ĭ Incomp. 1–ī . I=119° 10′.	In large grains and crystals. I . i–ī . O . Hexagonal cross sections, rectagonal longit. sections.	Interpenetrating twins multiples in I, more rarely in i–3	Opt. axis plane ∥ i–ī. Acute bisectrix ⊥ O. c′=𝔞 b=𝔠 ă=𝔟 $\rho < v$	Negative, feeble.	Brilliant as in quartz.

bb. Disappearance of obtuse

Zoisite.	$H_2 Ca_4 (Al_2)_3 Si_6 O_{26}$ Soluble with difficulty with separation of gelatinous silica.	3.22–3.36	i–ĭ Very complete Fracture parallel O.	Elongated grains and long, transversely jointed columns. I . i–ī , I=116° 26′		Opt axis plane ∥ i–ī always a′=𝔠=+ b=𝔟 ($\rho < v$) c′=𝔞 or when Opt. oxis plane ∥ O b=𝔞 ($\rho > v$) c′=𝔟 .	Feeble	Bluish gray, not brilliant usually.

**Pinite.* Large crystals = I . i–ī . i–ī . O . Polarizes as an aggregate. Occurs with quartz, orthoclase and biotite. Easily recognized macroscopically by the character of decomposition.

erferance *figure is visible; durable refraction negative.*

he acute bisectrix in O negative.

Colors of Polariz'n.	Color & refract.	Structure.	Association	Inclusions	Alterations	Occurrence.	Remarks.
Brilliant.	Colorless. flesh colored, relief strong. $\beta\rho$= 1.638 Pleochroism. $\mathfrak{a}$=dark blood red $\mathfrak{b}$=oil green $\mathfrak{c}$=olive green. $\mathfrak{c}>\mathfrak{b}>\mathfrak{a}$.	Rarely in grains, almost always columnar like staurolite. Often so full of inclusions as to obscure the andalusite. Often in radiating aggregates of long needles.	With quartz, orthoclase. biotite, muscovite	Sometimes poor. often as in metamorphic slates, rich in quartz grains, bitumen and scales of biotite	Often into greenish fibrous aggregates	Primary accessory in granite and cryst. slates. as metamorph. mineral in contact schists, etc.	Distinguished from augite by pleochroism and perpendicular extinction; from enstatite by character of double refraction; from hypersthene by color and double refraction, from zoicite by pleochroism. form of sections etc.; more difficult to distinguish from sillimanite which, however, occurs in minute needles.
Brilliant as in quartz.	Violet blue, colorless in very thin sections. β=1.54–1.56 $\mathfrak{a}$=yellowish white, $\mathfrak{b}$=berlin blue. $\mathfrak{b}>\mathfrak{a}>\mathfrak{c}'$.	Never in microlites. In large round grains or small crystals (in eruptive rocks.) A metamorphic mineral.	With quartz, orthoclase, and biotite With quartz sanidine, pleonast, and corundum.	Fluid inclusions, sillimanite needles, pleonast crystals, zircon, glassy inclusions.	Very frequent, particularly when occuring in grains. Changes to a fibrous green aggregate resembling andalusite (pinite).	Rare, as accessory, primary constituent of granite, quartz—porphry (pinite) and in grains in gneiss. Rarely in Trachytes and trachytic volcanics.	In thin sections much resembling quartz, but may be distinguished by the decomposition.
f obtuse bisectrix in O (negative.)							
Bluish gray, not brilliant usually.	Colorless-white. $\beta\rho$=1 70 relief strong.	The transverse fractures of the long columns is characteristic, also the inclusions.	With quartz, omphacite, garnet mica, and hornblende.	Fluid inclusions are numerous.	Frequently cloudy on the edges.	Frequent in crystalline slates as eclogites and particularly amphibolites.	Easily distinguish'd from apatite by optical peculiarities, from andalusite by cleavage in O, and the pleochroism and colors of polarizat'n. Never microlitic as Sillimanite. It differs from olivine in crystal form, etc.

urs with
racter of

II. b. 2. Monoclinic minerals.

a. Apparently hexagonal (or rhombic); highly perfect cleavage parallel O.

Name.	*Chemical comp. and reactions.*	*Specific gravity*	*Cleavage.*	*Usual combinations and form of sec's.*	*Twins.*	*Optical determinants.*	*Double refraction.*	*Colors [of] polarisation*
1. *Mica Group* a. Meroxene. (*Biotite*) b. Rubelane. Differs in the brownish red or seal red color from biotite of which it seems to be a pyrogene product of alteration. Occurs in basalts and lava. c. *Phlogopite.* Can be distinguished by chemical analysis and the yellow or light brown color A magnesia mica nearly free from iron	Mixture of $K_3\ (Al_2)_3\ Si_6\ H_3\ O_{24}$ and $Mg_{12}\ Si_6\ O_{24}$ in ratio of 1:1 or 1:2 (Tschermak) Decomposed by $H_2\ SO_4$ c'mpletely with formation of skeleton of silica.	28–3.2	∥ O very perfect. Separati'g in −1−3′ and ½ (1−i) correspondi'g to sliding or pressure planes.	I almost 120° I. i–i′. O. Thin plates or short columns. Sections parallel to O are hexagonal plates without fracture lines. Often with sliding planes and three systems of lines intersecting at 60°. The longitudinal section rectangular with numerous cleavage lines parallel to axis c′.	Rare. Twinning plane ⊥ I. Individu'ls distort'd so as to be attached in a plane almost parallel to O. Often int'rlamellated when only recognizable in polarized light.	Opt. axial plane ∥ i–i′ and parallel two opposite sides of the hexagon Acute bisectrix = $\mathfrak{a}$. varying little from the perpendicular to O. Axial angle usually very small = 5°–1.3°, variable, occasionally large, varying with the amount of iron. Disp. $\rho < v$.	Negative. Apparently perpendicular extinction & small axial angle make it appear hexagonal Cross sections apparently isotropous In convergent polarized light apparently hexagonal.	Not particularl[y] brillian[t] Browns In thin plates iridescen[t] carmine red.
d. *Anomite* (Biotite-pars)	According to Tschermak, a mixture of $H_2\ K_4\ (Al_2)_3\ Si_6\ O_{24}$ and $Mg_{12}\ Si_6\ O_{24}$ in ratio 1:1 or 2:1.		As in meroxene.	As in meroxene.		Optical axis planes ⊥ i–i′ $\mathfrak{a}$ almost ⊥ O. Axial angle 12–16° Disp. $v < \rho$.	Negative. Extinction perpendicular.	As meroxene.
e. Muscovite (and Sericite)	$H_4\ K_2\ (Al_2)_3\ Si_6\ O_{24}$ Insoluble.	2.76–3.1	Very perfect parallel to O. Sliding planes.	Rarely crystallized in rocks. Six sided plates.	As meroxene.	Optical axis plane ⊥ i–i′ $\mathfrak{a}$ slightly varies from c′, $\mathfrak{a}$ almost ⊥ to O Disp $\rho > v$. axial angle usually large, 60–70°.	Negative, strong. Extinction perpendicular. Apparently rhombic.	Very brilliant, irridescent, red to yellow.
2. Talc.	$H_2\ Mg_3\ Si_4\ O_{12}$. Unattacked by acids. Alkaline reaction.	2.69–2.8	Perfect ∥ O, (incomplete I.)	Never in crystals, in rocks usually as minute irregular plates like mica.		Optical axis plane ∥ i–i′, ∥ to a line of fracture. a almost at ⊥ to O.	Negative, feeble. Extinction apparently rhombic.	
3. *Chlorite Group.* a. Ripidolite (b. Clinochlor mon'clinic habit, strong pleochroism. Semicryst. and metamorphic.)	Mixture of $p(2\ H_2\ O.\ 3MgO\ 2\ Si\ O_2) + q(2H_2\ O.\ 2Mg\ O\ Al_2\ O_3\ Si\ O_2)$.	2.7–2.95.	Perfect ∥ O.	Scales and hexagonal plates I. O. as though hexagonal. If monoclinic I. i–i′.O.		Although often seeming hexagonal yet sometimes obviously biaxial with small axial angle $\mathfrak{a}$ ⊥ O.	Negative, feeble.	Not very brilliant, blue—green.

TABLE XII.

Colors of polarisation	*Color and index of refraction.*	*Structure.*	*Association*	*Inclusions.*	*Alterations*	*Occurrence*	*Remarks.*
Not particularly brilliant. Browns. In thin plates iridescent, carmine red.	Brown black, dark green $\beta=1.61$. Pleochroism strong in long't. sections 𝔞 and 𝔟 nearly alike In sections parallel to c—axis 𝔞=yellow-bright brown, at right angles *c* 𝔠=brown-black. 𝔠>𝔟>*a*.	Primary, as large crystals (in eruptive rocks) frequently fragmentary or with opaque margin, (comp. of first order); also in minute scales particularly in crystalline slates or scattered through the magma, as in basalts, etc. (comp of second order.	Usually with quartz and orthoclase, also with hornblende, and more rar'ly with augite and olivine.	Generally free from inclusions, but not rarely with fasciculate masses of epidote needles or regularly arranged slender needles of rutile.	Into chlorite like mineral, with epidote and calcite Loses its brown color, becomes green, calcite penetrates between the scales, needles of epidote appear. Also formation of limonite or magnetite on periphery.	In nearly all rocks In many as necessary primary constituent, one of the first to appear of the minerals. Product of alteration of augite, hornblende, rarely olivine. Contact mineral in metamorphic slates	Easily recognized by the cleavage and strong pleochroism. Cross sections not pleochroic as hornblende. Not green as chlorite, nor fasciculate.
As meroxene.	Red-br'wn Pleochroism feebler than in meroxene		With olivine and actinolite.		Becoming green to colorless, as above.	Rare in olivine store.	
Very brilliant, irridescent, red to yellow.	Colorless, light green oil green.	As primary in large plates In fasciculate and radiate aggregate. As secondary in aggregates of minute irregular scales In crystalline slates.	With quartz, orthoclase tourmaline.	Very poor Rarely needles of rutile, plates of specular iron, or columns of tourmalin, or Zircon.		*Occurrence.* Primary in granites (in particular in tourmaline granites) and crystalline slates, as gneiss, mica schists and slate. In no other rocks primary but as product of alteration in feldspars, chiastolite, liebenerite, etc.	Difficult to distinguish microscopically from talc. Sericite is but an unctuous, inelastic, light green muscovite, which occurs in irregular scales in certain crystalline slates.
	Colorless, white, light green.	Usually in irregularly felted or rosette-shaped radiating aggregates of minute scales.	With quartz, orthoclase, mica or with augite and olivine.	Very poor, biotite, actinolite. As muscovite.		A primary constituent in many crystalline slates. Not abundant Secondary product of decomposition of augites poor in iron and hornblende, particularly Enstatite altered to olivine stone and serpentine.	Microchemical treatment of isolated scales with fluorosilicic acid is the surest test.
Not very brilliant, blue—green.	Light to dark green $u=1.575$. Pleochroism feeble	Not in large scales but like talc as aggregates of minute irregular scales radiate or disperse.	With quartz, orthoclase, biotite muscovite as primary const.	Poor, hematite and limonite, needles of actinolite and rutile		Primary in chlorite slate. Decomposition product of mica, augite, hornblende and garnet	Also helminth, pennine, kaemmererite chloritoid, sismondine, and ottrelite. Rare.

2. *Crystals with* *Monoclin*

aa. Optical axis plane ⊥ i–i′; perfect cleavage

Name.	*Chem. Comp. and Reactions.*	*Specif. Grav.*	*Cleavage.*	*Usual combinations and form of sections.*	*Twins.*	*Optical determinants.*	*Double refraction.*	*Colors o Polariza tion.*
1a. *Orthoclase*	$K_2(Al_2)Si_6O_{16}$. Not attached by acids.	2.50–2.59 (2.57)	Very perfect Between O and i–i′ angle 89° 40′	In grains or columnar, O . i–i′ . I . 2–i . 2–i′ . 1 . Sometimes tabular or more rarely, in minute crystals. i-i′ I . O . 2–i . 1–i .	Frequent. (1) Oftenest according to Karlsbad type. Twinning plane i–i. (2) Baveno type. Twinning plane 2–i′. (2) Rarely Manebach type.	Optical axis plane inclined to O forming an an angle of 69° 11′ with vertical axis. $\mathfrak{c}$=b $\mathfrak{a}$: a = 5° Real axial angle =69°. In sections ‖ i–i′ or i–i a distorted bisxial interferance figure visible in convergent pol. light.	Negative, rather strong. In sections ‖ i–i′ one direction of extinction varies from the angle O . i–i (=$\mathfrak{a}$. a) by 5° 18′ Sections in zone O . i–i extinguish perpendicularly.	Rather brilliant but less than as quartz. In thin sections often less brilliant, bluish gray as in nepheline
1 b. *Sanidine.*			As above. Full of rifts.	In slender rods or large crystals, almost never granular. Sections ‖ O and i–i elongate bands truncate or acute at the ends. ‖ i–i′ distorted hexagons with sides corresponding to O . I . i–i . In the columnar type, sections rectangular if perpendicular to O . i–i′, if 2–i′ is present octagonal.	Twinning plane= O.	If parallel i–i′ $\mathfrak{b}$=b $\mathfrak{a}$: a=50°.		

Monoclinic Habitus.

cleavage ∥ O and i–i′; angle about 90°.

TABLE XIII.

Colors of Polarization.	*Color.*	*Structure.*	*Association.*	*Inclusions.*	*Alterations.*	*Occurrence.*	*Remarks.*
Rather brilliant, but less than as quartz. In thin sections often less brilliant, bluish gray as in nepheline	Generally cloudy white or gray, rarely clear. Colored red by limonite.	In large crystals or grains of the first order, more rarely in small grains or rods in eruptive rocks. Often coalesced with plagioclase. Zonary structure is rare as is zonal arrangement of inclusions.	With quartz, biotite, muscovite, hornblende and rarely with augite, plagioclase and elæolite.	In general poor. Specular iron, biotite scales, fluid inclusions, needles of apatite, zircon.	Kaolinization with formation. of muscovite or epidote.	One of the most abundant components in granular and porphyritic older eruptives. Essential comp. in granite, syenite, quartz porphyry and accessory in nearly all plagioclase rocks. Also in crystalline slates as gneiss, here often glassy like sanidine	Large crystals may be recognized by twinning in sections parallel to O and i–ı and by the oblique extinction parallel i–i′. Minute rods of it and sanidine in the magma of rocks often greatly resemble nepheline and certain melilites, Orthoclase lacks, however, the isotropous hexagonal sections. From plagioclase it may be distinguished by absence of the polysynthetic twins of the latter.
	Colorless clear. $\beta\ \rho = 1.5237$	In eruptive rocks as large crystals of first order and minute rods second order. The large crystals often fractured. Zonary structure.	As orthoclase also with nepheline and leucite but never with muscovite.	Very rich. Glass inclusions, usually zonal in arrangement. augite microlites and needles of apatite	Almost always unaltered Into opal in andesites and trachytes	Essential comp. (primary) in trachytes, rhyolites, phonolite, and the glass of orthoclase rocks. In nearly all later plagioclase rocks.	

bb. Optical axial plane ‖ i–i′; perfect cleavage in I=87°.

Name.	*Chemical comp. and reactions.*	*Specif. Grav.*	*Cleavage.*	*Unusual combinations & form of sections.*	*Twins.*	*Optical determinants.*	*Double refraction.*
1. *Monoclinic Augite Group* a. *Common and basaltic augite.*	$R\,Si\,O_3$ R=Mg. Ca, Fe, and $Fe_2\,O_3$ $Al_2\,O_3$ According to Tschermak a mixture of $Ca\,Mg\,Si_2\,O_6 + Ca\,Fe\,Si_2\,O_6 + Mg\,Al_2\,Si\,O_6$ Scarcely attacked by acids.	3.17–3.41 3.34–3.38.	Perfect I	Rarely in grains crystals I, i–i, i–i′ 1 and 1–i. O, —1 I=87°6′ Sections perpendicular to c octagonal with evident prismatic cleavage. Longitudinal section distorted hexagonal, with cleavage lines parallel to i–i′ quadrangular often rhombic.	Very frequent. twinning plane i–i, also in polysinthetic twins. More rarely interpenetrating twins in a plane of—1–i or 1–2′.	Optical axis plane ‖ i–i′, acute bisectrix =*c* in the obtuse angle β. b=b′. The positive axial angle enlarges with the amount of iron in rhombic augite, about 60°. Sections ‖ i–ī and perpendicular to c show the disappearance of an optical axis in almost the middle of the field.	Positive, strong. Extinction in sections ‖ b perpendicular; in sections inclined to i–i′ c: c becomes smaller until it reaches 0 when parallel to i–i In sections ‖ i–i′ c: c=39° 54′ a:a=22°.
b. *Diallage.*	do	3.23–3.34	I(87°), shelly fracture in i–i.		do	do	do
c. *Omphacite.*	do with more $Al_2\,O_3$	3.3	As in augite, fracture less perfect than in diallage.	Only in grains.	rare	do	do
d. *Diopside.*	more CaO than MgO poor in $Al_2\,O_3$	do		do	do	do	do
e. *Salite.*	poor in iron.	3.2–3.33.	Fracture in O besides the above.	Also in long columns with transverse fracture, usually not terminated. Section as in augite.	do	do	do

Colors of polarization.	*Color and Refraction*	*Structure.*	*Association*	*Inclusions.*	*Decomposition.*	*Occurrence.*	*Remarks.*
Very brilliant, especially in the light colored.	In section green to brown, often violet brown in basalt. The same crystal often exhibiting several colors. Pleochroism usually feeble. In phonolite it may be strong. c > a > b.	In large crystals (I. O.) with zonal alt'rnating colors. In twins these bands pass through both. Often with so-called "hour-glass" form, when sections parallel to i–i fall into 4 areas. Also in columns and microlites (II. O.) crystals often in large aggregates & radial groups.	Chiefly with plagioclase, nepheline, leucite, with or without olivine and biotite. Rarely with orthoclase, hornblende, and quartz.	Abundant glass inclusions, apatite needles and magnetite.	Into chlorite, calcite, limonite, epidote and quartz, ps'udomorphs of any of these after augite. Into opal. More rarely into hornblende, the form being retained but the cleavage that of hornblende. Into serpentine with talc and chlorite.	Later porphyritic eruptives as essential and primary, in diabase, augite andesite, and all basalts, also andesites, trachytes, phonolites. Rarely in large grains in older eruptives and crystalline slates.	Easily recognized by obliquity of extinction of c: c. the prismatic cleavage with angle of 87°, especially in cross section. Liable to be confused with hornblende in sections inclined to c. When augite is nearly colorless its polarization colors are vivid and like olivine.
do	Greenish brown. Pleochroism very feeble.	Only as large irregular grains. In inclusions, in fibrous and twinning characters much as bronzite. Often coalesced with ordinary augite, hornblende or mica.	With plagioclase, common augite, olivine, hornblende, and rarely with quartz.	Like bronzite with inclusions of brown scales of goethite? parallel to i–i. otherwise poor in inclusions.	At the ends changes into dark green strongly pleochroic hornblende fibres. Into viridite, also serpentine with formation of chlorite and talc.	Primary abundant in gabbro, norite, rare porphyritic eruptives. In olivine stone and serpentine. Rare in crystalline slates.	Often similar to bronzite in sections or plates parallel to i–i easily recognized.
do do Very brilliant	Grass green. do Light green—colorless. Relief strong.	Only in unaltered gr'ins poor in inclusions. Often coalesced with hornblende.	(c) With quartz, hornblende, garnet, zoisite, disthene, and rutile. (d) With olivine, chromite, diallage, & rhombic augite. (e) quartz, hornblende, scapolite, plagioclase, and titanite.	(c) Rare, fluid and rutile needles. (d) Rarely glass inclusions.		(c) In eclogite and amphibolite (d) In olivine stone (primary) rarely secondary alteration of garnet. (e) In crystalline slates.	Colors lighter than in augite proper (less iron). Differ from diallage in absence of complete fracture in i–i.

Name.	*Chem. Comp. and reactions.*	*Specif. Grav.*	*Cleavage.*	*Usual combinations & form of Secs.*	*Twins*	*Opticial determinants*	*Double Refract.*	*Colors of Polarization.*	*Color e*
f. *Acmite.*	Na_2 (Fe_2) Si_4 O_{12}	3.53–3.55	Complete I 87°, incomplete i–i.	In grains or long flattened columns (planes i–i being largest.) I . i–i . i–i′	i–i frequent.	As augite.	As augite.	As augite. Pleochroism rather strong. $\mathfrak{c}$=dark brown. $\mathfrak{a}$= brownish green. $\mathfrak{c}>\mathfrak{b}>\mathfrak{a}'$	Dark brown dark green β=ove 1.7.
g. *Wallastonite.*	Ca Si O_3 Completely decompos'd separating galatinous silica.	2.78–2.91	Parallel i–i, O and 1–i	I=87° Almost always in irregular fibrous long prisms	do	Opt. axis plane ∥ i–i′. Apparent axial angle=70°	Positive, strong. $\mathfrak{c}$ forms an angle with O of 32°–12′ $\mathfrak{a}$: c = 12°	Very brilliant.	Colorle yellowi white strong relief.
							cc.	Complete	cleavag
2. *Hornblende Group. Common & Basaltic Hornblende* [b. *Smaragdite* Compare uralite. Occurs with omphacite garnet, zoisite. and rutile.]	mR Si O_3 + n (R_2) O_3. R = Ca, Mg Fe. R_2 = (Al_2) (Fe_2). When containing much iron, attacked slightly by acids.	3.1–3.3	I very perfect with angle of 124° 11′; i–i and i–i′ imperfect	I . i–i′ . i–i and O . 1 or 1–i′ almost always in crystals. Cross sections usually hexagons also octagonal, longit. sections as augite.	Frequent i–i	Opt. axis plane ∥ i–i\. Acute bisectrix=$\mathfrak{a}$ falls in the obtuse angle β, $\mathfrak{b}$=b. Real axial angle about 79°. Positive axial angle varying with amt of Fe. Opt. axis disappears on edge of field ∥ O and i–i. $\rho<v$	Negative, rather less strong than augite. Extinction: $\mathfrak{c}$:c= about 15° (2–18°) $\mathfrak{a}$: c = 75° $\mathfrak{a}$: a′ = 29° 38′. $\mathfrak{c}$: c = 13–55° in green, 11–13° in brown hornblende	Less brilliant than in augite, yellow, green, brown.	Green brown $\beta\rho$=1.6 Pleochr ism rath er stron $\mathfrak{a}$= yellowish green honey yellow $\mathfrak{b}$=yellowish brown $\mathfrak{c}$=blac or gree ish brow $\mathfrak{c}>\mathfrak{b}>$
c. *Actinolite.*	Ca Mg_3 Si_4 O_{12} + Ca Fe_3 Si_4 O_{12} (Techermak) No Al. little iron.	3.026–3.16	As above, fracture transverse.	Long columns usually not terminated I . i–i\	More rarely.		"	"	Light dark green pleochroism feeble $\mathfrak{c}$=dar green $\mathfrak{a}$=yellowish
d. *Tremolite.* * (See next table.)	3Mg Si O_3 + Ca Si O_3 Preponderating Mg O. Insoluble.	2.93-3	I as above.	I . i–i long slender columns.		"	[$\mathfrak{c}$: c 15°] "	Very brilliant.	Colorles

Colors of Polarization.	*Color etc.*	*Structure.*	*Association*	*Inclusions.*	*Alterations.*	*Occurrence.*	*Remarks.*
As augite. Pleochroism rather strong. c=dark brown. a=brownish green. c>b>a'	Dark brown–dark green β=over 1.7.	In large crystals in syenite, often frayed at the end. In minute crystals yellow or dark green in trachytes and phonolites.	With elaeolite, sodalite, microline, and biotite.	Metallic particles.		Not rare in elaeolite–syenite, Phonolite, and trachytes.	
Very brilliant.	Colorless yellowish white. strong relief.	In fasciculate or radiate aggregates.	With calcite, green augite, granite.	Fluid inclusions.		(g) as product alteration of contact mineral rare in granular limestones, which have been the result of metamerphism. Rarely in phonolite etc.	(g) Very similar to tremolite, distinguished by angles of the prisin and solubility. Difficult to distinguish from zeolitic substances as scolezite.
Complete	cleavage I=124°.						
Less brilliant than in augite, yellow, green, brown.	Green-brown. $\beta\rho=1.62$ Pleochroism rather strong a= yellowish green or honey yellow. b=yellowish brown. c=black or greenish brown c>b>a.	In large crystals or grains I . O . rarely in small crystals and microliths II.O . Green hornblende often fibrous, brown zonal. Green hornb. often coalesces with augite.	With orthoclase plagioclase, quartz, biotite rarely with augite and olivine.	Poor. Fluid inclusions, glass and gas pores. Metallic particles and apatite needles.	Yellowish fibrous, epidote, calcite and limonite. Often on the surface to magnetite as augite. Into biotite, chlorite.	Primary essential in granular and porphritic eruptives, as syenite, diorite (green) porphyrite, andesite, trachyte (brown). Accessory in besalt (brown) olivine stone (green) rare. In crystalline slates (green) abundant. Essential in amphibolite slates and certain gneiss.	Distinguished from augite by prismatic cleavage angle. slight inclination of c : c and strong pleochroism. Biotite has not the cleavage and dichroism in sections parallel O.
..	Light to dark green. pleochroism feebler c=dark green. a=yellowish.	Needles or grains often fibrous.	With quartz, mica, chlorite and rutile.	Very poor.	*Occurrence.* (c) Rather frequent in certain crystalline slates lacking feldspar as talc–mica–and chlorite–schists and in serpentine.		(c) Almost always in long columns not in short crystals as in ordinary hornblende.
Very brilliant.	Colorless	In columns and fasiculate aggregates.	With calcite, olivine, hornblende, and diallage.	"	(d) As contact mineral in limestone. As primary (rarely secondary) component in slates and serpentine.		(d) compare wollastonite.

(e.) *Arfvedsonite.* Na_2 (Fe_2) Si_4 O_{12}. Specif. gr. 3.33–3.59. Occurs in large grains cleaving in I, with orthoclase, microcline, elaeolite and sodalite, rarely in elaeolite rocks. It is distinguished from hornblende by blue-green color and composition.

(b.) *Glaucophane.* Na_2 (Al_2) Si_4 O_{12} with Ca Mg. and Fe. Specif. gr. 3.1. It is an indigo blue mineral with strong pleochroism occurring in long fibrous needles

dd. Cleavage ‖ O and i–i; angle 115°.

Name.	*Chemical comp. and reactions.*	*Specific gravity*	*Cleavage.*	*Usual combinations and form of sec's.*	*Twins.*	*Optical determinants.*	*Double refraction.*
Epidote.	H_2 Ca_4 $(R_2)_3$ Si_6 O_{26}.	3.32–3.5	‖ O perfect and i–i forming angle of 115° 24′	Extended in the ortho-diagonal, generally small columns I. O. 1-i. i-i. Longitudinal sections ‖ i-i′ hexagonal. Cross sections ‖ O: i-i elongate quadrangular or extended hexagonal. Also in grains.	Plane i-i Rarely microscopic.	Optical axis plane ‖ i-i′ b=b acute bisectrix =a nearly coincides with c. Sections ‖ to i-i show a biaxial interference figure.	Negative, strong. Extinction a: c=2° 20′, c: ā′=27° 47′=c:O.
						ee. Cleavage imperfect in I or	
Titanite.	Ca Si Ti O_5. Decomposed by H_2 SO_4 Ti O_2 is dissolved, and gypsum formed.	3.4–3.6	I 133° 55′ 1-i′ 113° 30′, imperfect.	Usually crystalline I. O. ½(1-i′.) ½ (1-2′) or ⅔ (1-2′). Or in wedge-shaped grains.	Rather frequent Contact or inter penetrating twins in plane O.	Optical axis plane ‖ i-i′ acute bisectrix =c almost perpendicular to ½(1-i) strong dispersion of axes.	Positive; strong. Extinction a: c=39° 17′a-a′=21°.
Gypsum.	Ca SO_4+2 Aq. Soluble in acids with difficulty.	2.2-2.4	Complete in the clinodiagonal, less so -1.	In grains or long colamnar individuals. Crystals I. i-i′. -1.	Rare in microscopic individuals.	Optical axis plane ‖ i-i′ Acute bisect. =a. One optical axis almost ⊥ i-i forming with c an angle of 83°, the other an angle of 22°.	Negative strong. Extinction a: c=52° 30′ c: c=37° 30′.

often coalesced with hornblende, rarely in crystalline slates, eclogite, amphibolite, mica and chlorite-slates.

(g.) *Uralite* (Smaragdite in part) has the composition of hornblende but has a cleavage similar to augite. It is a product of the decomposition of augite and diallage. It occurs in gabbros and serpentine as well as augite porphyry.

TABLE XVI.

Colors of polarization.	*Color and index of refraction.*	*Structure.*	*Association*	*Inclusions.*	*Alterations*	*Occurrence*	*Remarks.*
Very brilliant, yellow to red.	Citron yellow, yellowish green. $\beta=1.72-1.75$. Pleochroism rather strong in thick columns. $\mathfrak{a}$=pale yellow, $\mathfrak{b}$=yellowish green $\mathfrak{c}$=greenish yellow $\mathfrak{b}>\mathfrak{c}>\mathfrak{a}$.	In long minute columns in chloritic substance or in pseudomorphs, rarely in grains.	With quartz, orthoclase, plagioclase, hornblende, biotite, augite and chlorite,	Very poor. Fluid inclusions.		Secondary frequently as decomposition product of feldspar, hornblendes, biotite, rarely of augite in eruptives & crystalline slates. In the latter also as primary.	Similar to augite. Characteristic is the yellow color, strong refraction and vivid colors of polarization.
1-i'; acute wedge-shaped sections.							
Not brilliant.	Faint yellow, reddish brown to colorless Pleochroism rather strong in dark varieties, $\mathfrak{a}$=reddish brown, $\mathfrak{c}$=greenish yellow	Surface of section rough. One of the first minerals to form in eruptive rocks.	With quartz, plagioclase, hornblende, augite, biotite, chlorite, quartz and other accessory minerals.	Very poor.	Rarely pseudomorphs of calcite after titanite.	As primary accessory in eruptives, granite, syenite, phonolite, schists, etc. Andesite, diorite.	Easily recognized by the wedge-shaped sections and rough surface.
Very brilliant, iridescent.	Colorless or colored by iron.	In minute grains and needles, rarely in crystals.	Rarely with clastic components, as quartz grains or scales of mica.	Fluid inclusions.		As a simple rock, granular or massive.	

a. Elongated columnar crystals, colorless or blu[e]

Name.	*Chem. Comp. and Reactions.*	*Specif. Grav.*	*Cleavage.*	*Usual combinations and form of sections.*	*Twins.*	*Optical determinants.*	*Colors of Polarization.*
Disthene. (Cyanite)	(Al_2) Si O_5 Insoluble.	3.48–3.68	Very Perfect. ‖ i–ī. Perfect ‖ i–ī and O.	Grains or columns i–ī. i–ĭ with an angle of 106° 15′, rarely terminated. Cross section quadrate (or hexagonal of i′–1 or i–1′ is added.	Frequent. Less so microscopic. Either multiples in i–ī or (2) perpendicular to c axis, or (3) to b axis, or (4) parallel to O.	Opt. axis plane makes an angle of 30° with the angle i–ī : O, with the angle i–ī . O an angle of 60° 15′ and, like the acute bisectrix = *a* stands at nearly a right angle with i–ī, parallel to which plane sections show a biaxial interferance figure with negative bisectrix.	Very vivid.
b. Broad tabular crystals or grains, colorless.							
Tricilnic Feldspars 1. *Microcline* (fibrous orthoclase.)	As orthoclase	2.54–2.57	Perfect ‖ O. quite perfect, ‖ i–ī, i′–1, i–1′.	As orthoclase i–ī . O . i′–1 i–1′ predominating.	Rare, ‖ i–ī and at right angles to it. Almost always interlammellate with orthoclase giving in sections ‖ O the characteristic "lattice structure." Also polysynthetic twins with albite, so that the O surfaces are parallel in each.	Opt. axis plane, almost ⊥ O, its section with i–ī forms with the obtuse angle O . i–ī 5–6° in the obtuse angle āc cleavage plates in i–ī show one axis evidently, the axial plane is somewhat oblique to i–ī.	Very brilliant.
2. *Plagioclase. Feldspars* (a) Albite [Ab]	Na_2 Al_2 Si_6 O_{16} Traces of Ca and K. Not attacked by acids. Si O_2 = 68%.	2.61–2.63	Complete ‖ O and i–ī incomplete i–1′ and 1. Angle O : i–ī at the right =93° 36′	i–ī . O . i′–1 . i–1′ . 1–i . 1 Very similar to orthoclase *Twins.* Almost always twinned. (1) Albite type i–ī, and generally polysynthetic. Often two such polysynthetic individuals are again twinned according to the Carlsbad type. (2) Percline type and these again united on the Manebach type. (3) By a union of (1) and (2) there results a lattice arrangement reminding of microcline.		Opt. axis plane forms an angle of 96° 16′ with the c axis, with the perpendicular to i–ī 16° 17′ Acute bisectrix = c. Dispersion slight, $\rho < v$, cleavage plates ‖ i–ī show a complete distorted interferance figure.	Usually quite vivid, not so strong as quartz. In very thin sections feeble blue-gray.

(or granular.) Cleavage in i–ī, i–ĭ, and O.

Double refraction.	*Color, etc.*	*Structure.*	*Association.*	*Inclusions.*	*Alterations.*	*Occurrence.*	*Remarks.*
Negative, *strong*. Extinction in sections ‖ i–ī $c : c = 36°$ $v < \rho$	Colorless or sky blue. $\beta\rho = 1.72$ strong relief. If blue, with rather strong pleochroism. c = blue a = white	In long columns or irregular grains with crevices ‖ or ⊥ to axis c. Often completely or mottled blue. Rarely in aggregates of needles.	With quartz, mica, garnet, omphacite, hornblende rarely with orthoclase.	Poor. Fluid inclusions.	Rarely margined. by a zone of alteration.	Rare as primary accessory in crystalline slates granulite, eclogite and mica schists.	If colorless, only to be distinguished from sillimanite by position of axis of elasticity.
Cleavage parallel to O. and i–ĭ.							
Negative, rather strong. In plates parallel to i–ĭ positive. Extinction not perpendicular but oblique in plates parallel to O.	Colorless Relief not strong, as in orthoclase.	In rocks only as grains, often coalesced with quartz, as in graphic granite.	(a) With orthoclase, elaeolite, sodalite, augite, and hornblende (b) With quartz, orthoclase, biotite, hornblende & muscovite (c) With the above and garnet and cyanite.	Usually very poor. Hornblende biotite, zircon, apatite	Similar to that of orthoclase.	Primary essential with orthoclase in (a) elaeolite–syenite. (b) in various granites particularly in graphic granite (c) Crystalline slates as granulite and gneiss.	Easily distinguished from orthoclase by extinction oblique to O and twinning; from other triclinic feldspars by latticed twinning and optical peculiarities.
Positive, rather strong. In cleavage plates ‖ O extinction inclined with the angle O : i–ĭ $+3° 54'$–$+4° 51'$; ‖ i–ĭ $+15° 33'$–$+20°$.	Colorless clear, slight relief. $\beta\rho = 1.537$	In large grains, rarely in crystals, often coalesced with orthoclase and quartz. In eruptive rocks in slender rods.	With calcite, quartz, mica and orthoclase, also chlorite and more rarely hornblende	Very poor, fluid inclusions.	Rarely altered. Becomes cloudy as orthoclase.	In granular limestone, frequent. In crystalline slates. In many semi-crystalline gneisses, phyllite, sericite slate. Rarely in eruptives, in grains in diorites, in rods in andesites and porphyrys.	All plagioclase is characterized by the polysynthetic twinning. Triclinic feldspars can only be distinguished by chemical means or determination of direction of extinction etc. Even then only in rather large grains.

Name.	*Chemical comp. and reactions.*	*Specif. Grav.*	*Cleavage.*	*Usual combinations & form of sections.*	*Twins.*	*Optical determinants.*	*Double refraction.*	*Colors of polarization*
b. *Oligoclase.*	Si O_2 = 62-66%. A little K (Ab_3 An_1 Ab_5 An_1.)	2.62-2.65 (2.63.)	Most perfect ∥ O, also i–ī as albite. O: i–ī=93° 28′ at the right.	As albite.	Always polysynthetic, of the albite type; also of periclinic type.	Very similar to albite. In cleavage plates ∥ i–ī the axial points lie farther out of the field of view than in albite. *c* inclined to the obtuse angle O: i–ī.	As albite. Extinction ∥ O inclined to angle O: i–ī +1° 10′; ∥ i–ī inclined 2°–4°.	As albite.
c. *Andesite.*	R Al Si_4 O_{12}, R= Na_2 and Ca. (Ab_3 An_1 to Ab_1 An_1.)	2.65	do	As albite.	As albite. Often with the albite and pericline type combined.	Similar to orthoclase but the axial plane is more than 15° inclined to obtuse angle O: i–ī. Disp. =$\rho<v$.	As above. Extinction ∥ O inclined to angle O: i–ī —1° 57′ to —2° 19′ ∥ i–ī—4° 50′ to 8°.	As albite.
d. *Labradorite.*	RAl Si_3 O_{10} (Ab_1 An_1 to Ab_2 An_3) Attacked by HCl.	2.68-2.70	As orthoclase in i–ī often with a play of colors.	Usually in large grains, rarely crystals, as orthoclase.	Individuals twinned ∥ i–ī are again twinned according to Carlsbad type or in i–ī or O.	In surface ∥ i–ī, lateral disappearance of one axis and signs of lemnisci axial point not visible; ∥ O lateral disappearance of the other axis, axial point also not visible. $\rho>v$.	As orthoclase. Extinction in O —4° 30′ to -6° 54′; i–ī, —16° 40′ to 21° 12′.	Usually very vivid.
e. *Bytownite.*	(A mixture?) Si O_2 = 49-45% (Ab_1 An_3-An.) More easily decomposed by HCl.	2.70-2.73 (2.71)	do	do	do	do	As Labradorite. Extinction ∥ O=-14.5° to 20° ∥ i–ī=-27° to 32°.	do
f. *Anorthite.* [An.]	Ca Al_2 Si_2 O_8 Si O_2 = 45—43%. Soluble in HCl without formation of gelatinous silica.	2.73-(2.75.)	Complete O and i–ī. P: M= at right = 94° 10′.	As albite.	As albibite.	Acute bisectrix =*c* at right angles to 2–ī. $\rho>v$. Plates ∥ O and i–ī show lateral disappearance of one or other axis. Axial point on margin of field.	As albite. Extinction ∥ O=—36° to 42° ∥ i–ī—37° to 43°.	As labradorite.

TABLE XVIII.

Colors of polarization.	*Color and Refraction.*	*Structure.*	*Association*	*Inclusions.*	*Alteration.*	*Occurrence.*	*Remarks.*
As albite.	Colorless, clear or cloudy, white to gray.	In large grains or crystals of I.O. and in minute slender rods (sections of thin plates Zonary structure and arrangement of inclusions. Twinning and concentric arrangement (as in orthoclase) both present.	With quartz, orthoclase, hornblende, biotite, augite and olivine.	Fluid (rarely) and frequently glass inclusions in later eruptives; augite and apatite microlites	Usually unaltered in later and cloudy fibrous in earlier eruptives Change into epidote ("saussurite") also to muscovite as in orthoclase and nearly all plagioclase.	Primary essential or accessory in eruptives. granite, diorite, diabase, gabbro, trachyte, andesite, also in basalt, and crystalline slates.	As albite.
As albite.	do	do	With sanidine, orthoclase, augite, hornblende, biotite and quartz.	do	Usually unaltered.	Primary essential in tonalite (quartz diorite), in andesite, in particular andesites, porphyries, syenite, also in cryst. slates.	do
Usually very vivid.	As orthoclase.	In grains and large crystals I.O. and microlites II O When twin'd upon both the albite and pericline type a lattice structure similar to microcline appears, but the bands are more distinct	With diallage, hypersthene, olivine, also with quartz, augite, hornblende, and biotite	Hornblende, olivine, diallage, magnetite, titanic iron. Acicular microlites are very abundant and lie ∥ c or the angle O: i-ī, and brown plates (ferric oxide or brookite?) which have their long axis at right angles to the microlites, or innumerable minute colorless or greenish grains (epidote?)	As orthoclase Often into epidote and muscovite.	Primary, essential, in norite, gabbro, dolerites, especially also in dacite, basalts, diorite.	do
do	do	do	With hornblende, augite, biotite, diallage, hypersthene	do but no microlites and scales.	do	Primary essential in eruptives, diorite, gabbro, andesites.	do
As labradorite.	Colorless, clear, as labradorite.	As labradorite.	With labradorite, augite, hypersthenite, olivine.	As oligoclase.	Usually unaltered, as the other plagioclase species.	Rather rare, primary essential in eruptives. In basaltic rocks and augite andesites, gabbro and norite. In crystalline slates, amphibolites, gneiss.	

Distinctions between the various plagioclase species.

The species lettered b–e are, as is well known, isomorphous mixtures of the two terminal members of the series—albite (ab) and anorthite (an). In physical and optical, as well as chemical characters, there are perfect transitions, and oligoclase, andesite, labradorite and bytownite are simply named members of the series.

As shown by Schuster's investigations, it is possible to distinguish the plagioclase species by determining the direction of extinction in cleavage planes parallel to O and i–ĭ.

The above given data of extinction refer to the customary position of the examined plagioclase, (the upper O surface inclines from left to right, as well as to the front,) and always to the obtuse angle O. i–ĭ, i. e. the surface ĭ–i lying to the right. The + sign in the case of cleavage plates ‖ O indicates that the direction of extinction is inclined to the obtuse angle O : i–ĭ in the direction of the right prismatic angle; in cleavage plates ‖ i–ĭ that it is inclined as i–ĭ with i–ĭ the — sign in both cases indicates the opposite direction.

C. *Aggregates.*

Aggregates are never dark between crossed Nicols because the numerous minute crystals are irregularly distributed. If the aggregate has a radial fibrous structure a fixed interferance figure may appear. Very often such aggregates may only he determined by chemical means.

1. *Serpentine* ($Mg_3\ Si_2\ H_2\ O_8$ + aq.) Specif. gr. 2.5–2.7. Green, yellow or brown, to black. Characterized by the mesh structure resulting from decay of olivine. In other cases the substance consists of large plates which may be regularly arranged at right angles to each other. It occurs as an independent rock mass or a decomposition product or pseudomorph after olivine.

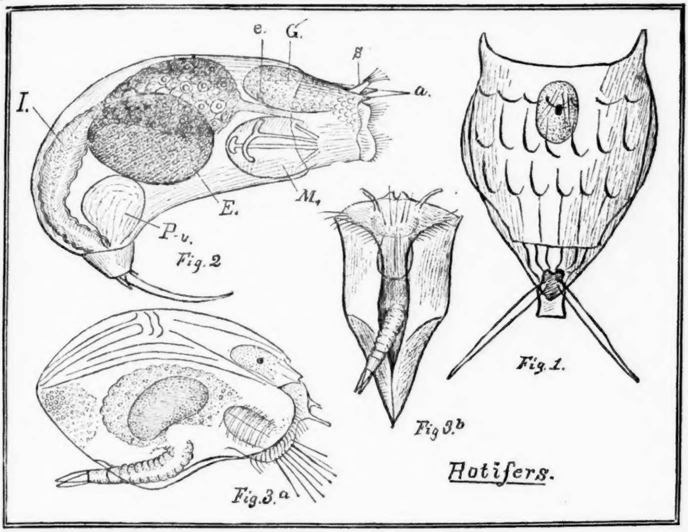
2. *Viridite.* Decomposition products of augites and hornblendes as well as garnet and biotite. (Delessite, chlorophaite, etc)

3. *Basite.* Decomposition product of pyroxene, very similar to serpentine.

4. *Chalcedony.* A secondary mineral except in quartz sphærulites.

5. *Zeolites.* Include natrolite, scolezite, stilbite, desmite, and chabasite.

6. *Carbonates.* Aragonite. Decomposing with effervescence in H Cl. Easily distinguished from calcite by crystal form.



Explanation of Figures.

Fig. 1. Distyla ohioensis, *sp. n.* (p. 54.)

Fig. 2. Diurella tigris, *Ehr.* (p. 49.) *M*, maxtax, *E*, egg, *G.* ganglion, s, sensory tube, *a*, spines of lorica, *I*, intestine, *Pv.* Pulsating vessel, *e*, eye.

Fig. 3a. Plœsoma lenticulare, *sp. n.*, side view.

Fig. 3b. do do. ventral view.

ERRATA.

Page 7, *line* 1, *instead of* preceding, *read* proceeding.

do 8, do 4. do do anteriorally, *read* anteriorly.

do 15, *Plate* I, *Fig.* 2. *instead of L. read f.*

do 48, *line* 21, *instead of* ampuliformis *read* ampulliformis.

do 59, do 12, do do Plate 1, Fig. III *read* Plate III, Fig. 1.

do 60, do 27, do do Asplanchnæa do Asplanchna.

do 61, do 33, do do ampuliformis do ampulliformis.

do 133, do 6, *et seq.* i–ĭ *read* i–i′.

do 135, do Under monoelinic, *instead of* i–ī and i–ĭ, *read* i–i′ in each case.

Table *VIII*, Apatite, instead of I,1 *read* I.1.

do *IX*, Olivine do do I=119° 2′ *read* I=130° 2′.

do *XI*, Hypersthene, under cleavage, *instead of* conchoidal fracture i–ĭ, *read* i–ī.

Table *XVII*. *Instead of* Tricilnic, *read* Triclinic.

do *XVIII*. Anorthite; cleavage, *instead of* i–ī *read* i–ĭ.

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The Natural History Department

OF

DENISON UNIVERSITY.

The work in Natural History is distributed as follows:

1. In *Biology*. The preparation assumed in such as is usually afforded in high and preparatory schools, viz: An elementary term in Human Physiology and Hygene and some preparatory work in Botany. In the Sophomore year the winter term is devoted to Comparative and Human Anatomy and Physiology. The genesis of organs and comparative (vertebrate) morphology is discussed as far as time permits. The hygenic applications of physiology are briefly presented but the physiology of the nervous system and comparative Psychology are relegated to the elective term of the Junior year. An amount of time equivalent to an hour per week is devoted to dissection and other laboratory practice.

In the following term elementary Botany is studied. The time is largely occupied with the study of phenogams and higher cryptogams. Field-work and plant-analysis supplemented by some laboratory practice in structural Botany accompany the use of the text book.

During the Junior year one term is given to Structural Botany and the study of the lower groups, including Algæ and Fungi. A part of the term is occupied with Plant Physiology. Three-fifths the time is devoted to the laboratory work. The class construct simple apparatus and conduct independently experiments in physiology.

A term in Zoology follows, and is occupied chiefly with the study of invertebrates. Begining with the cell and monocellular organism, types of each class are studied in the laboratory. In this way the developement of the vertebrate type is traced. The proportion of time devoted to lecture and laboratory work is as in the previous term.

An elective term in Zoology affords opportunity for work in Histology and special study in particular lines. It is intended to confine

study very largely to the vertebrate type and an exhaustive study of one organism or system is advised. The work is supplemented by a short course in comparative psychology on the basis of Wundt and Lotze.

Geology and Mineralogy.

In the spring term of the Sophomore year opportunity is offered scientific students to study mineralogy. The work is largely confined to the laboratory, and embraces blow-pipe analysis and the elements of crystallography. Some attention is given to economic mineralogy but assaying, etc., are considered to belong with the chemical department.

The Seniors study Dynamical and Historical Geology in the fall term using Le Conte's text book, supplemented by lectures on the simpler facts of structural Geology and extended tours to interesting localities.

In the winter term a course in Applied and General Geology varies with the exigencies arising. The course this year embraces the study of lithology, and the application of geology to the arts. Stratified rocks are studied with reference their macroscopic peculiarities and economic application. Metamorphic and igneous species are then studied by means of thin sections and the polarizing miscroscope. At other times paleontology is substituted.

OUTFIT AND APPARATUS.

For Botany an herbarium (to which additions have been received from Minnesota during the past year and a large collection is promised by Mr. Foerste) affords the needed illustrative material. A good set of compound microscopes with cameras, dissecting apparatus, staining and other reagents have quite recently been secured. Aquaria and a collection of conservatory plants will soon be provided, while the apparatus needed in vegetable physiology will be constructed by the students.

The Zoological laboratory is supplied with approved microtomes, and hardening, staining and conservative fluids, injecting apparatus, etc. We at present lack the costly apparatus for physiological investigation and records but it is hoped that this need may be soon supplied. Physiology is illustrated by prepared skeletons, casts, microscopic slides, etc., but much more is needed. The instructor will soon have ready a large suite of specimens illustrating comparative anatomy. The cabinet, though small, is rapidly augmenting, having more than doubled in effectiveness during the year past.

In Geology charts and illustrative material are of a good quality, but requiring many additions. The supply of type minerals and rocks has been materially increased. A lithological lathe and polarizing microscope of modern construction as well as over one hundred typical rock sections have been secured. Apparatus for applying micro-chemical tests is also supplied.

Although much has been done, there are many wants unsupplied. The room is much too limited and two additional appartments could be at once employed. The cabinets in all departments need great additions to make them adequate for purposes of illustration. To this end friends are earnestly solicited to send to the professor in charge specimens of any and all natural objects from various parts of the state. No animal or stone is so common (if perfect in its way) as to be useless. Contributions in money will be carefully expended to the same end in securing exotic specimens.

Directory of Colleges of Ohio, Etc.

ALPHABETICALLY ARRANGED.

ADELBERT COLLEGE, OF WESTERN RESERVE UVIVERSITY.

CLEVELAND, OHIO.

PRES. REV. CARROLL CUTLER, D. D.

Open to both sexes on equal terms.

Adjuncts: Medical Department, G. C. E. Weber, LL. D., Dean; Western Reserve Academy, Principal, N. B. Hobart, A. M., Hudson, O. Green Spring Academy, Principals, P. E. Laner, A. B. and M. J. Hole, Green Springs, O.

Two courses are provided in the collegiate department, leading to the degrees of Bachelor of Arts and of Letters respectively, and special courses with certificates, libraries contain about 12,000 volumes. The departments of Chemistry and Physics are well supplied with apparatus. The observatory is equipped with a five-inch equatorial and a three-inch meridian circle. The museum contains well-selected and increasing geological and other cabinets. Next year begins Sept. 9th, 1886.

BUCHTEL COLLEGE.

AKRON, OHIO.

PRES. REV. ORELLO CONE, D. D.

Three courses of study, these are:—The Classical, Philosophical and Scientific course, leading to the degrees B. A., Ph. B. and B. S., respectively. All studies are elective after the first term of Sophomore year. The faculty consists of eighteen professors and instructors. The college was founded by the Ohio Universalist Convention in 1870. Its outfit embraces an astronomical observatory fully equipped with instruments and improved physical and chemical apparatus and a cabinet of Natural History. Those designing to teach receive the benefit of regular instruction in methods of teaching. Year begins on the first Tuesday in September.

DENISON UNIVERSITY.

GRANVILLE, OHIO.

PRES. ALFRED OWEN, D. D.

Denison University comprises both a collegiate and a preparatory department. In the college department are three courses leading to the following degrees, A. B., B. Ph., B. S., with preparatory courses corresponding.

The college has eleven Professors and instructors, well equipped Chemical, Physical and Biological laboratories and a large and excellent library. The productive endowment exceeds $300,000. Instruction is thorough and expenses low. Those who cannot take a full course are permitted to take special studies when they can do so with profit to themselves and without injury to others. School year from Sept. 9, 1885, to June 24, 1886. The next school year commences Sept. 6, 1886.

HIRAM COLLEGE.

HIRAM, PORTAGE CO., OHIO.

PRES. GEO. H. LAUGHLIN, A. M.

Four courses, comparing favorably with best colleges in Ohio, viz:—Classical, Philosophical, Scientific, and Biblical. Faculty of twelve competent instructors. Total number of students 205, of whom 99 are ladies. Ample provision for instruction in music and drawing, as well as in the elementary branches. The outfit in science includes valuable collections of Western ores and fossils from Dr. F. V. Hayden and contributions from the Smithsonian Institute. Valuable additions have been made to the philosophical apparatus of the college. Tuition and board at reasonable rates. First term opened Sept. 1, 1885, and the year closes Thursday, June 17, 1886.

OHIO STATE UNIVERSITY.

COLUMBUS, O.

PRESIDENT, W. H. SCOTT.

The University has twenty-five professors and instructors. It offers eight courses of study leading to degrees as follows:—B. A., B. Ph., B. Sc., C. E., Mining Eng., Mech. Eng., B. Ag., and V. S.; preparatory course, a short course of two years in agriculture, and a course in pharmacy.

It possessess eleven well-equipped laboratories,—Physical, mechanical, chemical, metallurgical, agricultural-chemical, botanical, and physiological, and the most extensive and valuable museum of Ohio geology.

Its land, buildings, equipment and endowment are worth more than one million, one hundred thousand dollars.

OHIO UNIVERSITY.

ATHENS, OHIO.

CHAS. W. SUPER, PRESIDENT.

Classical, Philosophical, Preparatory and Normal departments. Instruction is chiefly given by the regular professors who are more or less specialists in their departments. Much new apparatus has recently been purchased to illustrate Physics and Chemistry. A chemical laboratory with gas and water has been provided. Young ladies are admitted to all departments upon the same terms with young men. One student from each county is entitled to a free scholarship, the conferring of which is in the hands of the county auditor and commissioners. Fall term begins Sept. 7, 1886, spring term begins Mar. 30, 1886.

OHIO WESLEYAN UNIVERSITY.

DELAWARE, OHIO.

C. H. PAYNE, D. D., LL. D., PRES.

Offers to both sexes, at surprisingly small expense, unsurpassed advantages for a full collegiate course or for special studies. Collegiate, Preparatory, Normal, Commercial, and Art Departments. First-class Conservatory of Music. Elegant home for ladies, with teachers. Necessary expenses per term $50 or less. As at present constituted, the museum embraces four distinct cabinets:

1. William Wood Cabinet of Casts of Fossils. 2. Mann Cabinet of Palæontology. 3. Prescott Cabinet of Biology, and 4. Merrick-Trimble Cabinet of Mineralogy.

The library embraces 13,786 volumes.

The study of the Bible is persued in some form by every student during his entire course.

BETHANY COLLEGE.

BROOKE CO., W. VA.

PRES. W. K. PENDLETON, LL. D.

Four courses, leading to appropriate degrees, viz:—Classical, Scientific, Ministerial and Ladies' courses; also special *Professional Courses* in Engineering, Practical Physics and Chemistry, with ample training in field-work and laboratory with use of instruments and apparatus. Now in 45th session. Alumni number 640. Expenses are reduced to a minimum, and every facility for economy in time and money is afforded. All classes open to both sexes. Year begins the last Monday of September, closing the third Thursday of June. For catalogueaddress Prof. W. H. Woolery.

LABORATORY SUPPLIES.

In order to facilitate the study of Natural History in Ohio the department has arranged to furnish such laboratory supplies as may be accessable in convenient sets adapted to college or high school or individual use. The business will be conducted by Mr. C. J. Herrick, while the preparation of the material will be under the immediate direction of the department.

No. 1. *Lithological suite* consisting of 25 hand-samples of type rocks with accompanying thin sections and a lithological microscope manufactured expressly for the department, also apparatus for making thin sections by hand, - - - - - $75 00

Lithological lathe (additional) - - - - - 50 00

No. 2. *Suite of stratified rocks*, 25 samples, accompanied by sections of the most important building stones and fossils typical of each rock and one of Bausch & Lombs' model microscopes, complete, - - - - - - - - - - - - $65 00

Sections of rocks or fossils will be made on application at a low rate. Other laboratory supplies will be secured and kept on hand as opportunity affords. Address C. J. Herrick, Granville, O.

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